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ROBERT LEDERER

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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MASTER OF DESIGN

IN

INDUSTRIAL DESIGN

DEPARTMENT OF ART AND DESIGN

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THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled:

Body Support System for Spinal Cord Injured Person in Exercising with Towing Machine

submitted by ROBERT LEDERER in partial fulfilment of the requirements for the degree of Master of Design.

The University of Alberta

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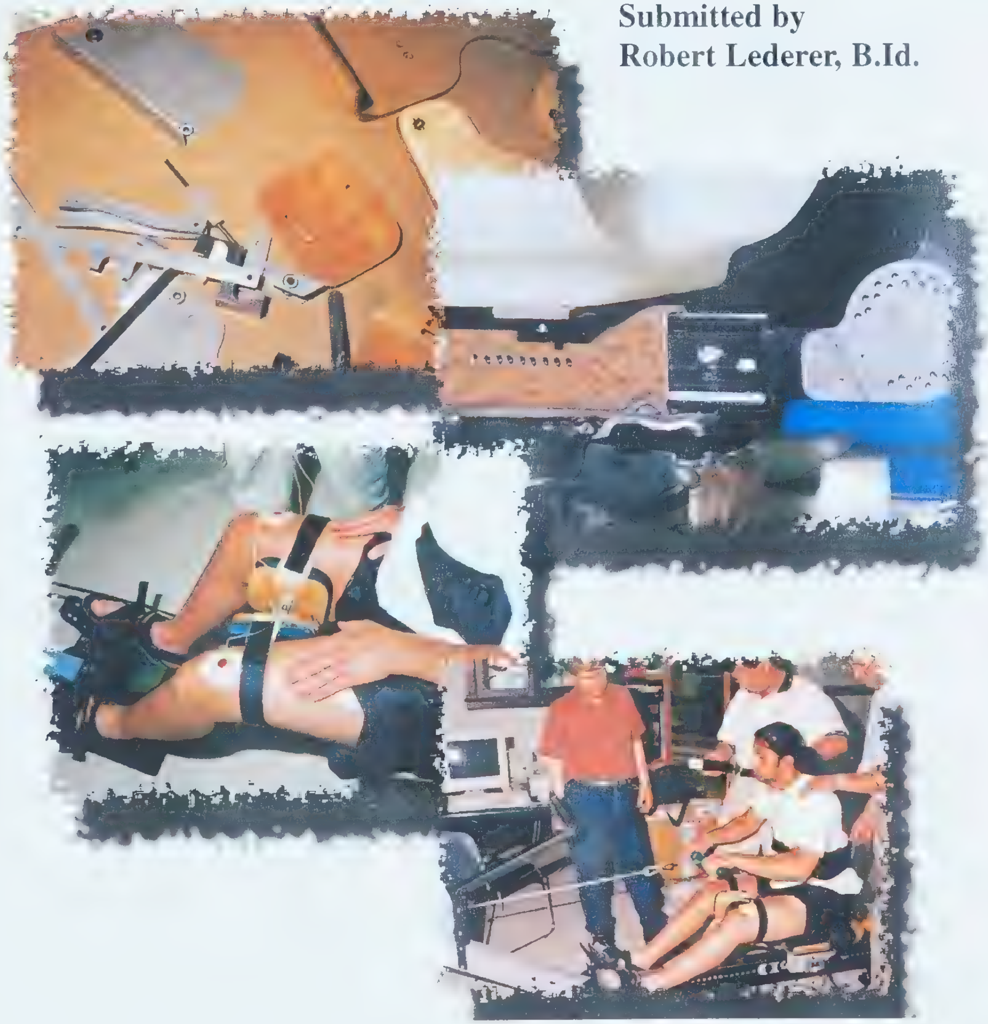
Design of a body support system for Spinal Cord Injured (SCI) persons when using Functional Electrical Stimulus (FES) to exercise for a comprehensive cardiovascular workout.

Submitted by
Robert Lederer, B.Id.



A written work in support of a thesis by project submitted to The Faculty of Graduate Studies and Research in partial fulfilment of the requirements for the degree of Master of Design in Industrial Design, Department of Art and Design.

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August, 1998

ABSTRACT:

This thesis outlines the development of an affordable exercise machine for use by spinal cord injured (SCI) persons. The developed machine uses a CONCEPT II indoor rower as the basis of the design which also permits its use by able bodied persons. To ensure an adequate cardiovascular workout the exercise routine of rowing was selected. Functional electrical stimulus was employed to assist the SCI users in performing the exercise routine.

ACKNOWLEDGMENT:

I thank the committee members, Professor Desmond Rochford, Professor Bruce Bentz, Associate Professor Lili Liu, Professor Peter Bartl and Dr. Gary Wheeler for their time and input. For his criticism, guidance and support I would like to recognize my supervisor, Professor Bruce Bentz. I would like to thank the Rick Hanson Center staff who accommodated all my requests, many with little prior warning. Thanks to Concept II and Supracor for donating the necessary equipment and materials.

I would like to acknowledge my wife for her assistance in editing, her patience and prodding to completing this work. A special thanks to Gerry Emas and Jerry Antflick for all their technical help and friendship.

TABLE OF CONTENTS:

PROBLEM STATEMENT:

In my three years of affiliation with the Rick Hansen Center I have become increasingly aware of the contribution I, as an Industrial Designer, might make to the improvement of exercising equipment. The existing equipment at the center consists of numerous commercially produced machines intended for public gyms. These machines were designed for able-bodied users. To accommodate spinal cord injured patients numerous ad-hock adaptations have been constructed by the staff at the center for their clients. One of the problems presented to me, was to develop the seating system for an exercise apparatus to provide cardiovascular training for spinal cord injured (SCI) persons. Presently, most available equipment is singular in its function; that is, it works only one area of the body. And, typically with SCI persons only that part of the body, which has not been affected through injury. Ideally, the equipment should be multi-functional and facilitate a number of exercise options and routines. The machine would ideally interface with F.E.S. (functional electrical stimulation) to allow for a complete body workout for spinal cord injured individuals. Ultimately, exercise routines for the SCI will be developed to enhance the equipment. Both able bodied and handicapped people should be able to use this equipment, which will enhance the acceptability of the exercise machine. The following concerns form some of the performance criteria for this equipment and are an integral part of the main problem.

1. Ease of transfer for SCI person from his/her main mobility device (wheelchair or walker) to the exercise machine
2. Consideration of the energy and time expended by a client getting set up in the machine
3. Potential to independently access the equipment and exercise routines
4. Adjustability for the various sizes of able bodied and SCI persons
5. Use of simple mechanical solutions and easily obtained components to keep costs down and make it easy to repair and service
6. Visual comparability with other home exercise equipment, and it should not look like a machine for a person with a disability.

BACKGROUND:

Lack of physical exercise for both able bodied and SCI is the number one risk factor for the development of cardiovascular disease and early death (Janssen et al., 1997) (Pate et al., 1995). The rational for developing the rowing exercise machine is to provide the opportunity for an SCI person to purse a quality form of cardiovascular exercise.

During my early visits to the Center, Dr. Gary Wheeler, Research Director for the Rick Hansen Center, brought to my attention the need for exercise routines. He informed me of a research project that he had worked on in 1993 in which he and several other researchers developed an F.E.S. assisted rowing machine to enhance cardiovascular training in people with spinal cord injuries. From this preliminary research "the results suggest that the rowing machine represents a potentially valuable hybrid training device that may significantly reduce risk factors for cardiovascular disease and improve the quality of life of people with SCI." (Laskin et al., 1993).

After reading the article, further discussions took place with Dr. Wheeler and Professor Bruce [illegible] co-ordinator Industrial Design program. The beginning of a master's project as outlined in the problem statement was established. The problem statement suggested that the design of the equipment could form one part of a larger possible project. The concerns of SCI persons and the needs of rehabilitation institutions could be jointly considered. It was necessary to have a piece of equipment to conduct research programs, and one, which could also be used by these institutions to monitor patient's progress. To further enhance the design of the equipment, it was concluded that specific electronics and training routines or protocols should also be developed.

A research/design development team appeared to be the best solution for this task. This team was put together under the direction of Dr. Brian Andrews (biomedical/rehabilitation engineering specialist) and Dr. Gary Wheeler (research director Rick Hansen Center / PhD in exercise physiology.) The electronic control systems for both the F.E.S. and other monitoring systems would be designed by Rahman Davoodi (electrical engineer). The seating system to support the SCI

person in a suitable position and allow them to interact with the equipment, and to perform the exercises required would be my responsibility.

The design team met and established general objectives that are outlined in the clinical trial application. " In view of the difficulties in providing effective exercise choices for persons with SCI, we are working to develop an exercise device which fulfills the following objectives:

1. Adequately stresses the cardiovascular system to produce training effects.
2. Recruits sufficient muscle mass for central and peripheral training effects.
3. Provides an effective, affordable, simple and adaptable home-based exercise device for use by persons with SCI and other family members." (Wheeler, 1997)

RESEARCH:

SPINAL CORD INJURY STATISTICS:

Most of the current statistics on SCI persons in North America has been collected by the National Spinal Cord Injury Statistical Center (NSCISC), at the University of Alabama in Birmingham. The recorded data has been collected over the last 22 years. Canada has very similar causes of SCI (with the exception of gunshot wounds). Therefore, most of the facts and statistical information can be transposed and the numbers adjusted according to the population of Canada. It is estimated that the annual incidence of SCI, is between 30 to 40 cases per million in the U.S. Based on the 1992 census population of 254 million this corresponds to between 7,600 to 10,000 new cases each year. As Canada's population is 1/10th that of the states, that would equate to 760 and 1000 new cases per year. SCI primarily affects young adults. Fifty-seven percent of SCI persons are between the ages of 16 and 30 years old, the overall average age of SCI at injury being 31.1 years. The database indicates 82.1% of all SCI are male, about 4 to 1 ratio to female. Since 1991, motor vehicle accidents have accounted for 35 % of cases, followed by acts of violence (including gun shot wounds) 30.4%, falls 19.5%, sports 8.1% and all others 6.9%. Trends in the database show that the proportion of injuries due to motor vehicle crashes and sports activities has been declining while those attributed to acts of violence have increased steadily since 1973. Previously, as with most handicaps, an SCI person was forced to live out the remainder of their life in an institution such as a nursing home. Today 89.2% of all persons with SCI who are discharged from the hospital return to their homes, 4% go to nursing homes, the remaining 6.8% go to hospitals or group living situations.

FUNCTIONAL ELECTRICAL STIMULUS

Functional Electrical Stimulus is a technique used to activate muscles (or sensory organs) that may not be performing correctly due to injury, disease, or a physical abnormality. F.E.S. can describe a variety of therapeutic and experimental treatments. Within the last few years examples of FES

technology have included a device called a cochlear implant for the ear. This enables individuals with sensorineural deafness to hear certain kinds of sound. In addition, phrenic nerve stimulators are implanted devices that can help people breath without a respirator. F.E.S. for SCI involves restoring movement to a person's paralyzed arms or legs. Adrian Kantrowitz (Peckham, 1987), in 1960 demonstrated the attachment of electrodes to the skin of a person with paraplegia and applied an electrical current to stimulate the muscles. The placement and application of the stimulus enabled the person to stand and take a few steps. Since that time, numerous research applications have taken place. Attaching electrodes to the skin in order to achieve muscle movement in a clinical setting is not difficult. The challenge is in applying F.E.S. to allow an individual to perform daily routines.

The sequencing of electrical stimulus to the muscles will create specific movements. These movements are relatively crude in their degree of control. The paralyzed limbs being moved have severely reduced sensation, function and lack any sensory feedback for fine motor control. The ability to determine muscle and bone damage, fatigue or stress is also a major problem when applying FES. Sophisticated computer control systems are being developed to overcome and minimize some of these particular problems. (Peckham, 1987)

An important consideration in the use of FES for muscle stimulation is getting the muscles back in shape after months or years of atrophy. The most common physiological problems below the level of the nerve lesion are the atrophy of the muscles, osteoporosis or brittle bones, and lack of peripheral blood circulation. Inactivity of the body area leads to these problems due to the in-operation of the muscle pump. The reconditioning of the body area affected by paraplegia using FES can reduce a number of medical complications resulting from immobilization notably, cardiovascular disease. (Stover et al., 1995)

EXERCISE EQUIPMENT FOR SCI:

1. ERGYS 2 Rehabilitation System, produced by Therapeutic Alliances, Incorporated., Fairborn, Ohio.(cost US $10,855.00)(fig.1).

The ERGYS Rehabilitation System uses computerized FES to allow people with little or no voluntary leg movement to actively pedal a stationary leg-cycle ergometer with the power of their own muscles. The computer generates a low-level electrical pulse, transmitted through surface electrodes, which cause coordinated contractions of the leg muscles. Sensors located in the equipment provide continuous feedback to the computer to control the sequence of muscle contraction as well as the resistance to pedaling. The ERGYS employs mechanical restraints designed to limit the user's range of motion. A single seat adjustment during the pre-run setup establishes a pedaling geometry that defines the maximum and minimum degrees of flexion of the hip and knee joints of both legs. Alignment of the knees that follows in a straight plane movement is achieved by reciprocating leg restraints strapped to the user's thighs.

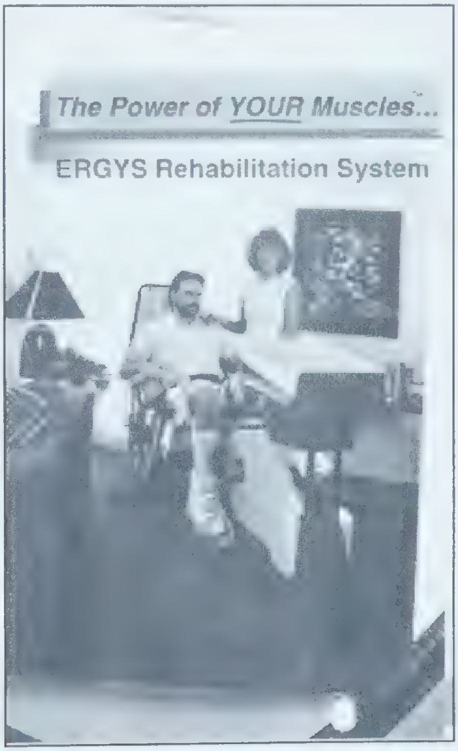


Fig. 1

2. Pro II produced by SINTIES SCIENTIFIC.INC., Tulsa, Oklahoma.(cost US $3,838.00) (Fig. 2)

The Pro II is a passive leg exercise machine that uses the cranking of the arm pedals to simultanously rotate the leg pedals. Figure 2 shows the setup of the Pro II where the participant remains in their mobility device (wheelchair) which is secured to the frame. The lower part of the legs are restrained in a support boot. Once secured in the equipment the SCI person can modify the resistance of the cranks both for the arms and the legs. The ERGYS 2 and the Pro II exercise the paralyzed limbs. Other exercise equipment specific to SCI works only the unaffected portions of the body.

Fig. 2

3. POWER TRAINER FLEX, SINITIES SCIENTIFIC.INC., Tulsa, Oklahoma. (cost US $1495.00)(Fig. 3).

The Flex allows for a complete upper limb and trunk workout with the possibility of over 40 types of exercises that can be performed while seated in a wheelchair. Latex resistance instead of weights and pulleys provide a range of 8 to 120 pounds of resistance for each exercise.

Fig. 3

4. Wheelchair Ergometers (Fig. 4)

Many of these are home made from cycle rollers or other adapted configurations of primary wheel rollers and frame restraints. By placing their wheelchair on the rollers they are able to exercise by turning the wheels using their arms.

Fig. 4

SEATING FOR SCI:

(ABLEDATA FACT SHEET #10, 1990)

Good seating positioning for persons with SCI allows them to function as independently and safely as possible. The exercise equipment outlined earlier uses either the patient's wheelchair or other support systems to hold the patient in positions that accommodate exercise routines. Whether the patient is in a wheelchair or a specifically designed support, certain design factors need to be considered.

Types of Seating Systems:

1. <u>Planar or linear</u> seating refers to the use of flat planes or surfaces to support the user when sitting. These components are usually fitted with hardware that permits adjustment for growth and physiologic change. When these boards are covered with foam or other cushioning material, this system allows adaptations to suit the user's needs.
2. <u>Modular contoured</u> seats use components with generic contours. With a variety of sizes and configurations of support pads and hardware they allow the system to be fitted to the user. Contoured components provide better distribution of pressure and increased comfort because they more closely match the shape of the user's body contours.
3. <u>Custom contoured or molded</u> seating involves custom forming the seating system around the user's body contours. This type of system provides greater surface contact with the user's body and results in improved comfort but requires a higher level of fitting and fabrication technology than in 1. and 2.

Seating Components:

1. Seat: The most important aspect of the stability in the seating position is control of the pelvis or hips. A good base of support can enhance a person's ability to balance, reach, propel, transfer, or perform many tasks. A seating system begins with a solid seat insert that can distribute pressures over as broad a seating surface as possible. This is to both to maximize the base of support and to minimize pressure in concentrated areas. The size, angle, and shape of the sitting surface and the composition of the material used for cushioning all influence how well a seat works.
2. Pelvic Support: Proper alignment of the pelvis can maximize the user's stability on the seat. A lapbelt or pelvic strap can secure the hips all the way back in the seat, and the angle at which it crosses the pelvis can maintain control of anterior or posterior pelvic tilt. Lateral hip guides can be placed on the sides of the hips to help keep the pelvis centered on the seat. Sculptured padding can also provide alignment and support for the hips and pelvis.
3. Back and Trunk Support: The addition of a solid back insert, whether flat or contoured, can provide better support for the sacrum and the spine and increase trunk stability. A flat or contoured back can be modified with additional pads to provide lumbar support, shoulder protraction, or gentle lateral trunk support. Anterior trunk support is sometimes needed for individuals with an SCI who pulls or falls forward. This support can be provided with lateral trunk supports that curve around to the front. A variety of harnesses or anterior supports that incorporate straps and pads can support the abdomen, sternum, and / or shoulders. It may also be appropriate to consider mounting the seating system on a chassis that reclines or tilts back to relieve the user's spine and head from the forward pull of gravity.
4. Foot and Leg Support: Foot or leg rest height should be set to relieve some of the pressure on the under-surface of the thighs. The angle of knee flexion or extension can play a crucial role in the user's ability to stay seated back in the chair. SCI people with hamstring tightness will need to keep the knees flexed more or the muscle group will pull on the pelvis and extend the hips.

SEAT CUSHIONS FOR SCI

(ABLEDATA FACT SHEET 11, 1991)

The choice of cushion can improve posture, increase comfort, and distribute pressure to prevent skin breakdown, and enhance the users functional ability and sitting endurance. The type of cushion used can affect motor and sensory function, prevent skin breakdown, guard against orthopedic problems, encourage bowel and bladder function, and the methods of transfer in and out of wheelchairs. There are two major concerns for an SCI person in their choice of seat cushions, to prevent skin breakdown and poor posture.

1. Skin Breakdown: People who lack sensation or who have trouble shifting weight and changing positions are at risk for skin breakdown. Decubitus ulcers or pressure sores can result from excessive or prolonged pressure while sitting or lying in the same position. They can also occur through skin shear from sliding, heat and moisture buildup, and from repeated trauma. Poor nutrition, poor circulation, low muscle tone or bulk, age, and poor posture can also make a patient more susceptible to skin breakdown.
2. Posture: Proper width and depth ensure pressure distribution over as much of the sitting surface as possible. The use of a firm base beneath a cushion can improve pelvic positioning and help distribute pressure more evenly. The pelvis forms the primary weight bearing area during sitting. The correct form of cushion can help correct and compensate poor posture brought on by the lack of normal muscle tone, and the lack of sensory functions that afflict most SCI persons.

Types of Cushions Materials:

Foam

Foam is the most common material used in cushion construction. The most important property of foam, which is considered in selecting a cushion, is its density. (measured as the indentation load deflection) Foam's ability to spring back repeatedly over time, air circulation, dissipation of heat and water, and urine resistance are other performance factors for consideration. A flat foam cushion distributes weight by compressing to varying degrees beneath the person sitting on it. The bony prominence's of the pelvis will greater compress the foam than the sides of the thigh and as such sufficient padding is needed to ensure the foam does not fully compress ("bottom-out"). Softer foams tend to provide better pressure relief than stiffer foams, but they offer less postural support or stability. Contouring or molding the foam to suit the shape of the user can reduce high-pressure areas, improve posture and stability by holding the pelvis back in the seat and keeping the legs abducted.

Flotation

These are cushions that have a sealed envelope filled with a moveable substance such as water, air, or gel. The cushioning is provided by the substance in the envelope, it responds to the movements and changes in posture of the person sitting on it. These cushions can distribute weight more evenly but run the risk of "bottoming-out" if the moveable substance thins out too much around the area of high pressure. The dynamic nature of a flotation cushion, tends to make them less stable for precise posture control. A hybrid or combination of cushion types can combine the best characteristics while eliminating some of the drawbacks. For example, using a gel pack under the areas of high pressure with a foam cushion supporting the rest of the person is preferable to either gel pack or foam on its own.

that could be incorporated into the design. The CONCEPT II (Appendix B) rowing machine was chosen, because it is the industry standard for training professional rowers and because it is commonly used in the home. The production numbers and worldwide distribution network results in affordability and ease of servicing. The development of an exercise machine suitable for SCI and able bodied will require numerous modifications. The following design criteria are necessary:

1. to assist SCI a seat will need to be modified in order to support low and high lesion persons
2. facilitate ease of transfer
3. be stable
4. provide adequate comfort to avoid pressure sores
5. maintain leg alignment with track
6. allow ease of change from SCI use to able-bodied (Wheeler et al., 1998)

The need to facilitate many different sizes of SCI persons and their varied physical abilities requires an adjustable modular seating arrangement. This arrangement will require components with generic contours and padding and the necessary hardware to allow for minor adjustments (ABELDATA FACT SHEET #10, 1990). As the SCI client progresses through the exercise program their physiological changes will require that the equipment change with them; e.g. as the client strength increases an increase in machine resistance is required Most seating for SCI has been designed for sitting in a static position, that is, even when powering a wheelchair the lower trunk and legs are held or supported in a non-active mode. The design challenge is that in rowing the whole body is in a dynamic situation. Forces and pressures are being applied and are also changing throughout the exercise routine. The design and selection of materials for the support system will need to allow for these changes as well as the problems of body heat, moisture buildup and possible skin sheer.

The initial prototype will allow for testing the geometry of operation and will be evaluated using able-bodied persons for the necessary feedback regarding possible areas of high pressure that may prove problematic to SCI. This information will help refine a second model that can be used for the first clinical trials.

DESIGN:

The approach to designing the support system was to first analyze the existing custom fit plastic bucket system that was used in the first clinical trials (Laskin et.al,1993). By examining the measurements and geometry of this first seating arrangement and then relating them to the design criteria earlier defined. This first prototype support enabled me to verify measurements and experiment with other features, that the team and I felt were important. The approach to the seating was to adopt the modular contoured form (ABLEDATA FACT SHEET #10,1990) concept because we needed the seating to accommodate various sizes of patients and the changes which may occur as a patient progresses in the exercise program.

Figure 5 (pilot study 1993) shows the custom fabricated seat mounted on the undercarriage derived from a steno-chair mechanism. This allowed the whole seat to tilt back and return forward to an upright position as the client rowed. The tilting action mimicked the rocking motion that was typical with able- bodied rowers.

Figures 6 & 7 show the separation necessary for the plastic form to become adjustable. By drilling numerous adjustment holes in the plastic forms they could be placed in the optimum position. Besides holding the torso in position it was also necessary to keep the lower limbs travelling in the correct line to the seat and rowing resistance wheel.


Fig. 5


Fig. 6


Fig. 7

Figure 8. Illustrates the under seat attachment of the leg alignment brace, which can be adjusted for different lengths of legs. Placing pins in the circular drilled holes can also stop the degree of rotation. This restricts the amount of flexion of the client's knees and avoids damage to the knee ligaments.

Fig. 8

The inner thigh supports shown in Fig.9, connect to the under seat alignment brace bracket and hold the thigh in place by an adjustable elastic strap.

Fig. 9

The initial trial with an able bodied person revealed a number of problems. The upper body support was too restrictive in allowing full shoulder movement. The development of a new lumbar and upper torso support as seen in Fig.10 has minimum elements to restrict the rowing dynamics. An adjustable spine element, which allows for the custom fitting of these pieces, was also incorporated.

The first working prototype used by an SCI person is shown in Fig. 11. The results from the first trial pointed out some areas of deficiency. Unlike people with full movement, the SCI have limited pain sensation or kinesthetic sense, which varies according to the level of injury and do not respond to the forces exerted on their bodies in those areas as an able bodied person. The body movement and the reaction of the support system to these forces proved different than when we had an able bodied operator. Alternative dual systems for supporting the body were developed and tested as in Fig. 11.

Fig. 10

Fig. 11

Figures 12, 13, 14, 15 show an upper torso elastic brace and a crutch elastic support together. The crutch brace was rejected as it applied too much pressure and could restrict blood flow to the legs. In the first trial as the client fatigued his ability to hold his legs in full extension for the arm pull became a problem. His knees would bend and he would fold up negating the arm exercise portion of the routine. To eliminate this problem it was decided to incorporate a brake into the system that would hold the seat stationary while the arm pull phase was being done. An electrically operated brake was designed and located underneath the seat to address this problem.

Fig. 12

Fig. 13

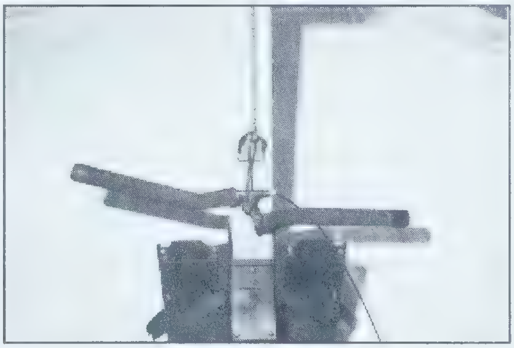
Fig. 14

Fig. 15

However, the power required for operating the brake made it incompatiable with some of the other design objectives (low cost, ease of change from SCI to able bodied). The new brake operates from the action of the pull stage of the rowing cycle routine. This force is transferred by a cable to the lever under the seat which moves up to force the cycle brake shoes to press against the top of the Concept II seat beam. Figures 16 & 17 show the brake arm attached to the underside of the seat carriage and the first brake handle developed from an existing cycle brake lever. The elongated arms were attached to the brake lever and covered with foam. By pulling back and with a slight rotation of the wrist the brake could be activated.

Fig. 16

Fig. 17



On review by the team it was decided that we should try and keep the original handle as not all SCI persons will have the ability and strength to operate the brake in this manner. To activate the FES, thumb buttons are being placed on the handle. The less the user has to think about his actions, the easier it would be to learn. By connecting the handle to the cable and placing a resistance spring at the brake lever we were able to adjust the brake so as to co-ordinate the stopping action with the arm pull phase of the rowing routine. Fig. 18. This not only solves the problem of the legs folding when fatigue sets in but we can turn off the FES stimulus to the quads giving the muscles a rest during the

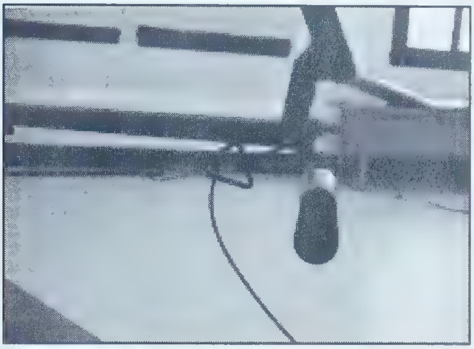


Fig. 18

arm pull phase. The rest period became crucial in extending the exercise program to achieve an adequate cardiovascular workout. For safety concerns it would be necessary to provide a system of stops to limit the movement of the seat both forward and backward. It is important not to over extend the legs and lock the knee when moving forward or that the knees do not fold too tightly making it difficult to extend and push the seat back. In both cases ligament and muscle damage can occur. Initially we achieved this by placing "C" clamps to the track so that the seat carriage hit the clamp and stopped. This worked, except it caused an abrupt stop, which jarred the user. Because the operator had no prior warning that his forward or backward movement was coming to an end it became a jarring stop. A dampening stop system that would not diminish the activity or waste energy was needed. Two gas struts with rubber damping ends were mounted to the seat carriage Fig. 19. An adjustable stop that could be moved to accommodate the various user sizes, and is part of the rowing machine rail, is pulled out and moved along to its correct position for the user. Fig. 20.

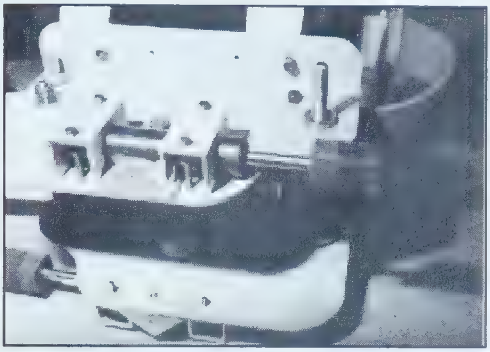


Fig. 19

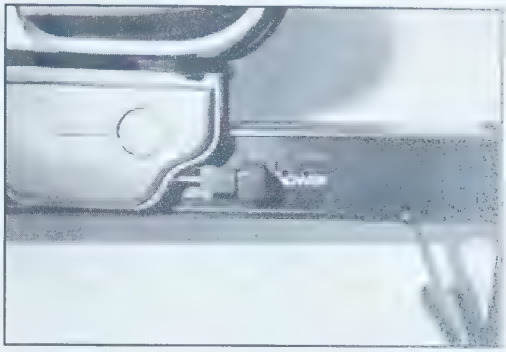


Fig. 20

At this stage of development the team felt we had addressed all the concerns from the first trial and that an improved seating system was ready to be undertaken. The second prototype would also address the following criteria of function:

1. allow the seat to change from SCI seat to the able bodied version
2. choose materials that have the appropriate aesthetics for home use equipment
3. make as many of the elements suitable for independent use by the operator who has SCI

Figures 21, 22 show the second prototype prior to the beginning of the clinical trials. The design consists of a central spine element that holds the upper shoulder brace, lumbar board and stretch harness for the upper torso support Fig. 23. The single steel spine curves at the lower end to attach under the seat to the wheel carriage system. This curve allows for the flexing that was part of the first prototype system. The upper torso support, lumbar board, thigh supports and the seat form are all made of laminated plywood. These were configured to allow for variations of body sizes and are also adjustable along the seat back spine member. Figure 24 shows the lumbar support, the adjustment slots and the lower chest harness attachment points. Plywood was chosen to conform to the design criteria of making the design not look a typical machine for the handicapped. Through my research of home exercise machines various wood elements are part of their designs. Figures 25, 26, 27 show the molds and forms that make up the parts for the prototype.

Fig. 21

Fig. 22

Fig. 23

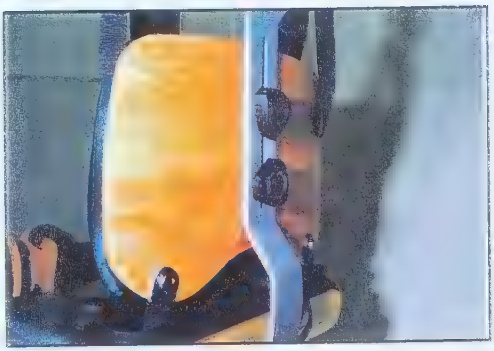


Fig. 24

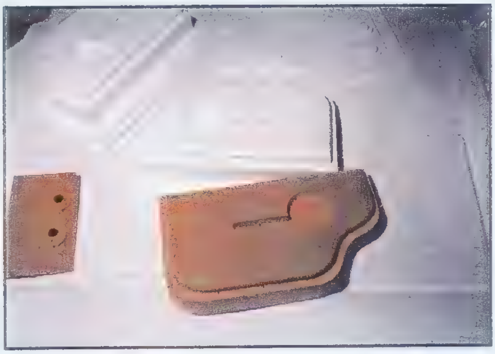


Fig. 25

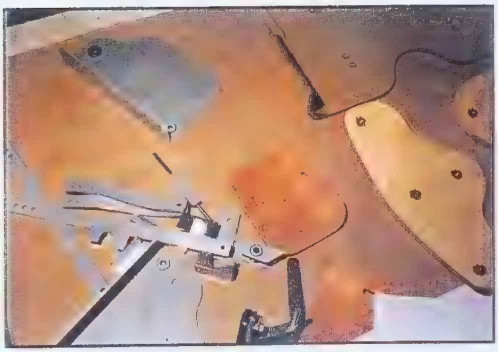


Fig. 26

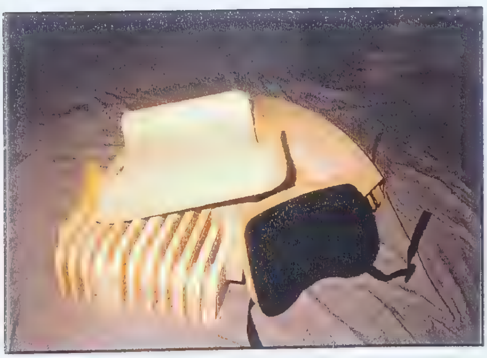


Fig. 27

Figures 28, 29, 30 show the thigh braces, which keep the legs, aligned with the seat and the rowing machine track. The braces are positioned on the thighs with the stretch elastic straps that wrap around the thigh muscle and are held in position with Velcro.

Fig. 28

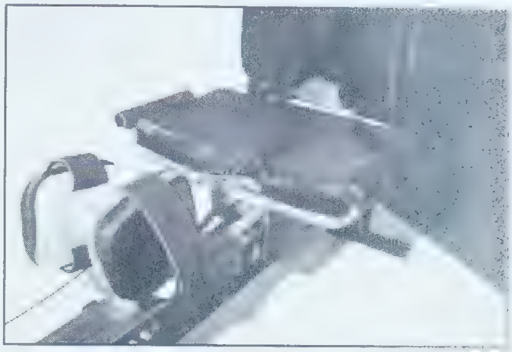


Fig. 29

Fig. 30

The upper torso support and lumbar board cushions are made of a new cushion material system called STIMULITE (Appendix 2). This form of cushioning provides many of the necessary performance features needed for this style of exercise equipment. Lightweight, with a ventilation system to reduce heat build up, it also allows moisture to evaporate and air to circulate. The seat has the same material, STIMULITE, with the addition of a layer of 1" T-Foam to further cushion the patient and avoid the possibility of bottoming out and creating a pressure sore. The thigh alignment brace is padded with 1" T-Foam as it offers excellent cushioning and stability. All cushioning is covered by four way stretch spandex material that allows the necessary give to the cushioning material to custom form around the body parts of the operator. This material also has good ventilation properties and is easy to clean.

The CONCEPT II rowing machine comes with an electronic performance monitor (see Appendix B) mounted on an arm positioned in front of the flywheel. To facilitate the independent use of the machine by a SCI person the arm was extended. This allowed the rowing handle retaining clip to be mounted underneath the extended arm bringing the handle within arms reach of the user who is strapped into the seat support. On the standard model the clip and the handle where located on the steel frame between the feet straps and the flywheel. Fig. 31.

The second prototype setup ready for testing Fig. 32.

The SCI subject advised the team of his first impression of the exercise setup. This input and our observations and assessments, as we tested, have initiated more changes to our design. Fig. 33, 34, 35, 36.

Fig. 31

Fig. 32

Fig. 34

Fig. 35

Fig. 35

Fig. 36

DISCUSSION OF THE DESIGN:

The first prototype set out to meet a number of criteria:

1. To find a combination of support elements to hold an SCI person when attempting to perform the exercise routine of rowing
2. To examine the geometry between the body support elements and the existing rowing machine components
3. To select and test materials for suitability in a clinical trial model

The short test session and evaluation of the first prototype with a SCI person allowed us to verify some of the criteria, in particular:

1. the required ranges of movement and the dimensions of the thigh support connecting arms
2. the positioning and ranges of adjustments for the lumbar support and seat
3. the required amounts of cushioning to avoid bottoming out

Along with this information we also learned that:

1. The tilting back and seat were too reactive. The client experienced far too much movement resulting in a waste of energy. Which in turn affected the rythym of leg and arm stroke co-ordination. The rowing style this created was not in keeping with our initial design goals of replicating an able-bodied routine.
2. As the SCI test subject had low levels of endurance in his legs it became evident that on the arm pull phase his leg strength could not hold him stationary as required. He folded at the knees negating that part of the rowing stroke.
3. The chest restraint did not hold him as upright as was needed.
4. The "C" clamps used for the limit stops, created an abrupt stop and too much of a jarring effect on the equipment and the user.

The second prototype was designed to incorporate the successful elements from the first trial and address the shortcomings. It also focussed on addressing more of the goals we outlined at the beginning of the project. These are:

1. To select the materials to enhance the user's acceptance of the machine for both able bodied and SCI
2. Facilitate ease of transfer from wheelchair to rowing seat
3. Change easily from SCI seat to a standard seat system
4. Increase the potential for the SCI user to independently access the use of the equipment
5. Consider the choice of materials and components to keep costs down and make it inexpensive to repair and service

The second prototype was tested and the response by the SCI user was encouraging. He had little hesitation in approaching the machine and was able to transfer without too much difficulty. The cushioning was adequate and on examining his skin after the first trials there was no indication of redness or pressure marks. The lumbar support, seat and thigh pads were easily adjusted to accommodate his size. The limit stops, incorporating the gas struts, not only allowed for a smooth stopping action they also converted some of this energy into helping to reverse the direction of the seat. The back support for the aluminum seat rail on the rowing machine was modified to allow the quick transfer from the SCI seat to the able bodied seat. The handle activated brake system, although sensitive in the beginning of the rowing cycle, performed well. The extended bracket to hold the rowing handle allowed the user to independently access the handle.

After the third trial by the SCI user, problems appeared in the structure of the seat carriage. The bearing supporting the front top roller of the seat undercarraige seized due to the load being applied by the user. Once the user was strapped into the seat, a two-foot lever action was created whenever he became slightly misaligned with the seat-rowing rail. This torquing not only damaged the bearing it made the brake system inoperative, because the brake shoes were not parallel with the

track. On these longer trials the upper elastic chest and shoulder harness became an irritant to the user and began rubbing on his neck. This was in part due to the excessive springing that occurred on the steel spine support. As the user became more comfortable in the seat he was able to apply more vigor in the exercise and these problems became more pronounced.

The modifications to solve these problems appear to be working. A new seat undercarriage has been built and in the last trial it performed well. The new carriage allowed for a modification to the [illegible] system to make it less sensitive to start the sequence of the exercise routine. The steel spine support has been reduced in length minimizing the torque effect on the seat carriage. Welding a lateral steel bracket to the lower curved area on the back steel spine dampened the excessive springing. The user requested that the vertical angle of the seat to the lumbar support be increased. He felt more secure when transferring if the angle was increased. The shoulder chest harness is being replaced with an upper chest belt and shoulder stabilizing straps. This should stop the neck rubbing but will still hold the upper part of the torso with the lumbar board.

In evaluating the success of the present design, it has met a number of the team's initial objectives:

1. An easily transferable seating system for SCI and able-bodied using a standard rowing machine
2. It incorporates many elements in the design that allow an SCI user to independently access the equipment and set up alone for exercising
3. It is fully adjustable for various sizes and levels of injury of the user
4. Many of the components used are inexpensive to purchase and are easy to obtain
5. The choice of materials, colors and forms are comparable with other home exercise equipment

The work on this project is going to continue past this presentation. The following concerns now need design solutions.

1. The development of an auxiliary activation of the brake to hold the seat stationary whilst the SCI user transfers would be an advantage
2. The mounting of the electronic FES control circuit board and battery pack into the side covers of the seat carriage
4. New foot straps which allow easier (independent) securing of the user`s feet

CONCLUSION:

In summary, the primary goal of the project was to develop a seating system for a rowing exercise machine that would provide cardiovascular training for spinal cord injured persons. The design to date has achieved this goal. A commercially available rowing machine has been modified to be functional for both SCI and able-bodied. We now have a seating arrangement that supports and allows an SCI person to perform the exercise of rowing in a similar manner as that of an able-bodied person. Most of the performance criteria have also been met: ease of transfer, independent set-up, adjustable support elements, use of simple mechanical solutions and components, and the device is visually comparable to other home exercise equipment.

Representatives of CONCEPT II are interested in further testing and development to better evaluate the viability of a commercially available kit. The kit would be purchased along with the over the counter model rowing machine. A unique feature of this project was that in all the other forms of exercise for SCI only one part of the body is being exercised while the remainder is being held static. In our design the whole body is involved in the exercise and is also in a dynamic situation, experiencing forces of action and reaction.

Possible future research that may grow out of this project would be to gather data about the action reaction forces. This can be done by placing strain gauges at the various points of movement of the seat, thigh pads, feet cups and back support areas. Along with these gauges, pressure pads would be placed on the body support elements of the system to measure the forces being applied. Understanding the pressures and directional forces that apply could be invaluable to a designer in designing better exercise and daily living products.

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APPENDIX A: Rowing Routines

An outline of the rowing routine which was to be performed by an SCI person when operating the rowing machine.

Full Rowing Cycle (Concept 11)	Expanded Cycle	Expanded terminology 1.	Expanded terminology 2.
1. Catch	1. Catch	1. Knees flexed 2. Lean forward 3. Chest to knees 4. Arms extended	1. Tucked or Compressed position 2. Knees fully flexed 3. Chest forward to touch knees 4. Arms fully extended 5. Shoulder in front of buttocks or hips
2. Drive	2. Drive	1. Drive with legs	1. Drive with legs 2. Drive to full extension of legs 3. Back straight 4. Arms fully straightened
	3. Backswing or “Lean”	1. End of leg drive 2. Extend the back	1. End of leg drive 2. Controlled, powerful extension of back 3. Extension of back to slight backward lean
	4. Pull	1. Pull with arms	1. Powerful pull with arms 2. Pull through to lower chest (just below ribs)
3. Finish	5. Finish	1. Arms pulled through to chest 2. Back lean 3. Legs extended 4. Pause (slip)	1. Arms pulled through to chest 2. Slight back lean 3. Legs extended fully 4. Pause and glide

4. Recovery	5. Recovery	1. Snap wrists 2. Push away 2. Slide to front stops	1. Snap wrists (to clear oar from water) 2. Push away with arms and extend to clear knees 3. Knees bend slide forward to beginning position - knees tucked - chest to knee - arms extended
5. Catch	6. Catch	1. Knees flexed 2. Lean forward 3. Chest to knees 4. Arms extended	1. Tucked or Compressed position 2. Knees fully flexed 3. Chest forward to touch knees 4. Arms fully extended 5. Shoulder in front of buttocks or hips

Rowing Cycle: Version 1. (Concept II and Wheeler, 1997)

Phase	Details
1. Beginning of drive	1. Knees fully flexed - fully "compressed" 2. Chest/torso touches knees 3. Shoulder in advance of buttocks 4. Arms fully extended 5 (holding handle)
2. Mid Drive	1. Legs half extend/half flex 2. Knees at 90 degrees 3. Shoulders infront of buttocks 4. Arms fully extended
3. End of Drive	1. Legs fully extended 2. Shoulders past buttocks 3. Arms pulling to body
4. Beginning of Recovery	1. Arms travel away from body 2. Shoulders remain behind buttocks 3. Legs fully extended
5. Mid Recovery	1. Arms fully extended away from body 2. Shoulder slightly infront of buttocks 3. Legs between extension and flexion
6. End of Recovery	1. Arms fully extended 2. Shoulders infront of buttocks 3. Legs fully flexed 4. Knees (almost) touching chest

Rowing Cycle; Version 2. (Rodriguez et al. 1990)

<table>
<tr><th>Phase of Rowing Cycle</th><th>Instructions phase 1.</th><th>Phase of Rowing Cycle 2.</th><th>Instructions phase 2.</th></tr>
<tr><td>1. Catch</td><td>1. Knees fully flexed or compressed
2. Chest (almost) to knees
3. Shoulder ahead of buttocks (hips)
4. Arms fully extended
5. Firm grip of handle</td><td>1. Catch or Start Phase</td><td>1. Knees fully flexed or compressed
2. Chest (almost) to knees
3. Shoulder ahead of buttocks (hips)
4. Arms fully extended
5. Firm grip of handle</td></tr>
<tr><td rowspan="2">2. Drive</td><td rowspan="2">1. Drive with legs
2. Drive to full extension
3. Back straight
4. Arms fully extended
5. Extend back to shoulder past buttocks with arms straight</td><td>2. Beginning of drive</td><td>1. Drive forcibly back with legs
2. Arms fully straight
3. Shoulder ahead of buttocks (hips)</td></tr>
<tr><td>3. Mid Drive</td><td>1. Shoulder infront of buttocks
2. Arms fully straight
3. Knees at 90 degrees</td></tr>
<tr><td rowspan="2">3. Pull</td><td rowspan="2">1. Legs fully extended
2. Back lean shoulder behind hips (buttocks)
3. Powerful pull of arms to below rib cage</td><td>4. End of drive</td><td>1. Legs fully straightened
2. Torso extends - shoulder behind buttocks</td></tr>
<tr><td>5. Pull</td><td>1. Arms pull firmly towards body
2. Pull towards below lower margin of ribs</td></tr>
</table>

4. Finish	1. Arms pulled in tight below ribs 2. Legs straight 3. Back lean	6.Finish	1. Legs fully straight 2. Body extended - shoulder behind buttocks 3. Hands pulled in below margin of ribs
5. Recovery	1. Wrist roll (to clear oars) (note: not required for ergometer) 2. Push away to straight arms past knees to full extension of arms 3. Shoulders remain behind hips and legs straight 4. Legs flex as slide forward to full flexion	7. Beginning of recovery	1. Push arms away 2. Body extension and legs straight 3. Arms fully extended 4. Begin slide forward
		8. Mid recovery	1. Sliding forwards 2. Knees at 90-degrees 5. Shoulders move slightly ahead of buttocks
6. Catch	1. Knees fully flexed or compressed 2. Chest (almost) to knees 3. Shoulder ahead of buttocks (hips) 4. Arms fully extended 5. Firm grip of handle	7. End of recovery and Catch	1. Knees fully flexed or compressed 2. Chest (almost) to knees 3. Shoulder ahead of buttocks (hips) 4. Arms fully extended 5. Firm grip of handle

Rowing Cycle 3: Integrated Instructional System. (Concept II/Wheeler/Rodriguez et al. 1997)

APPENDIX B: Proprietary Items

Technical support on the Concept II rowing machine, cushion material by Supracor and T-Foam by AliMed Inc.

Concept II Indoor Rower

The complete exercise


There is something about rowing
that captures you and never lets you go.
The acceleration of one stroke leads you
on to the next as the boat surges through
the water. The boat's momentum empowers
you with a sense of enormous strength.

ROWING...

The complete exercise

What is it that makes rowing the superior fitness activity for a lifetime? There are many other choices: running, walking, stepping, biking, weight-lifting, skiing, but none as complete as rowing:

- Rowing exercises all major muscle groups: **legs, arms, back, abdominals, and buttocks**. Legs provide most of the power of the rowing stroke; your upper body adds the rest. Rowing is one of the few aerobic activities that can strengthen your back.
- Rowing exercises muscles through a wider range of motion than most other exercises, thereby **improving and maintaining flexibility** around some of the major joints. This also makes the exercise more satisfying because the rower has more of a sense of motion.
- Rowing provides **aerobic conditioning** as well as **strength conditioning**.
- Rowing is **a great calorie burner**. Recent research showed that rowing burns calories faster than biking at the same perceived level of exertion. In other words, it feels easier to burn more calories while rowing than while biking.
- Rowing is **a lifelong sport**, able to be enjoyed by all ages, from kids to grandparents.
- Rowing is a smooth motion, rhythmic and **impact-free**.
- Rowing is **versatile**: you can row indoors or out, on water or on land, competitively or not, intensely or easily.
- Rowing is **time-efficient**. It doesn't take long to get a great workout that offers all the features listed above.
- Rowing is the complete exercise – one workout that is satisfying and enjoyable to do and provides **a balance of fitness benefits**.

For all these reasons, you will be more likely to stay with rowing than with other forms of exercise.

More than just a machine...

A lifetime membership

When Pete and Dick Dreissigacker first started Concept II in 1976, they weren't thinking about rowing machines. Their first product was a new composite racing oar, designed for college crews and national rowing teams. Within a few years, the Dreissigacker oar had become the new standard for the rowing community–and it still is. It was used by 95% of the crews in the 1992 Olympics. In 1981, the first Concept II Rower was produced. It, too, rapidly took hold with rowers around the world.

Unlike the oars, the Concept II caught on quickly with people who had never rowed on the water. Its popularity has grown steadily while other rowing machines have come and gone. Why? There's the high quality and excellent feel of the machine. There are the many advantages of rowing as a complete form of exer... what really sets Concept II apart is ... company behind the machine. We ... support for our customers that rang... technical help to motivational progr... continues to grow in response to c... requests and enthusiasm

> "Buying a Concept II is like joining a club with free lifetime membership"

From the beginning, the custo... been our top priority. The machine ... well-designed and built to last. It ha... satisfy the high standards of Olympi... and hold up under constant use by ... rowing teams. The price for the end ...

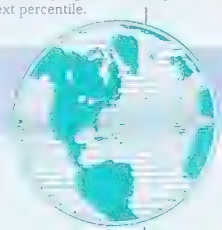
'81 '82 '83 '84 '85 '86 '87

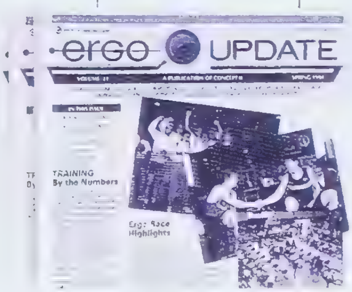
Model A
Introduced in 1981

1st C.R.A.S.H. B. Sprints

Model B
Introduced in 198...

The World Ranking: In 1985, we started publishing an annual listing of scores for 2500 meters on the Concept II. Scores are ranked in 10 year age categories and two weight classes. Even if you are near the bottom of the list, the Ranking offers you a way to measure progress and the goal of moving up to the next percentile.





The Ergo Update was introduced in 1982. Its circulation has grown to 130,000 world-wide

Million Meter Club. It doesn't matter how long it takes you. We'll send you a certificate and patch to recognize your achievement

kept affordable by making a commitment to direct sales. Direct technical support was also made a priority.

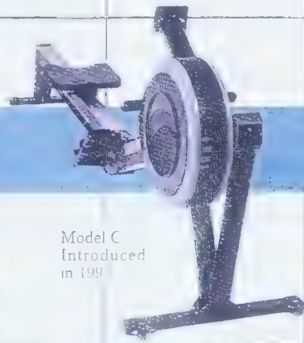
The first issue of our newsletter, the Ergo Update, was mailed out in December 1982. The Update is our way of regularly communicating with you, even if you don't call us. Two times a year, it provides you with indoor rowing news, training ideas and product information.

Our customers have been a driving force in many innovations. Take Indoor Racing, for example. It was started by a group of rowers in Boston in 1982. They were looking for a way to spice up winter training so they held a competition. They had 6 Concept II Rowers and 90 people. They called it the C.R.A.S.H.-B. Sprints.

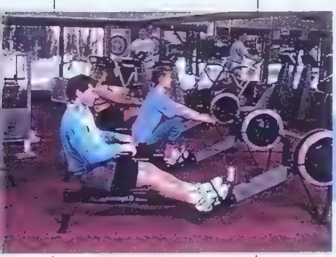
Thirteen years later, the descendant of that first race is now called the "World Indoor Rowing Championships" and boasts about 1000 participants from around the world. It is one of 80 or more races in over 17 different countries. And there are many smaller events as well. Not everyone will be a World Champion, but many people of all abilities do find that competition adds challenge, camaraderie and a goal to their fitness program.

We like to think that the purchase of an Indoor Rower will be the beginning of your relationship with Concept II. Our customers are our best spokespeople.

'88 '89 '90 '91 '92 '93 '94



Model C Introduced in 199



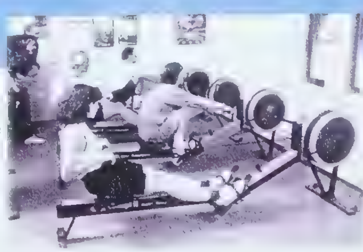
Team Million Meter Club. Teamwork, camaraderie. Whether for a health club, a school, a corporate fitness center, the CII Team Million Meter Club provides a wonderful group incentive.

1992 C.R.A.S.H.-B. Sprints

5 Million Meter Club: It wasn't long before our first Million Meter Club members were asking us what was next! Besides receiving a second patch and certificate, you'll get a Five Million Meter Club T-shirt

The World Ranking has grown each year to include over 11,000 names from over 30 different countries!

Kids' Distance Clubs: Our goal is to encourage fitness and fun, and not to stress the competition. Kids' distance goals are determined by their age, and it doesn't matter how long it takes to reach them. Their award is a patch and a certificate



10 Million Meter Club. This is our newest club. It was the request of our 5 Million Meter Club members. In addition to a special patch and the certificate, you'll receive a 10 Million Meter Club sweatshirt

Performance Monitor 2 (PM2)

The second generation of our Electronic Performance Monitor is standard on every machine

We have designed the PM2 to be as friendly as possible while making several powerful functions available to you. There are three levels of operation:

Level I **Automatic Operation:**
Like the original PM, the PM2 has an automatic mode which will monitor your workout without requiring you to use any buttons at all

Level II **Preset Workouts and Recall:**
To introduce more variety into your exercise program, you can set up 4 different kinds of workouts on the PM2: preset time duration, preset distance, timed intervals, and distance intervals. Recall lets you view your workout when you are done.

Level III **Extra Functions:**
Advanced users can take advantage of a variety of extra functions and formatting options

Your elapsed time how long you have been rowing.

Your total or cumulative output since you started rowing. This is displayed in a choice of 4 units: Average Pace, Meters, Calories, or Watts. During pre-set workouts you will also be able to choose to see your Projected Finish Time or Distance

Your stroke rate or cadence in Strokes per Minute (SPM)

Your output for each stroke: how hard you pulled on the last stroke. This is displayed in a choice of 3 units: Pace/500 meters, Calories/Hour, or Watts

Optional Heart Rate Interface
The PM2 is preprogrammed to receive and display heart rate data from the Polar [illegible] chest belt. Your heart rate will be continuously displayed during your workout, and will also be stored for recall after your workout. The receiver mounts easily beneath the monorail and plugs into the PM2. The adjustable chest belt contains electrodes which sense your heart rate You may purchase this optional package with your Indoor Rower, or at a later time

The seat design is the product of several years of experimentation and field-testing. It is contoured to maximize comfort for the serious rower. The seat glides on a roller system which is designed for stability and durability.

The monorail is an I-beam aluminum extrusion which combines lightness and strength with a stainless steel rolling surface for the seat.

Four members of the Concept II Design Team (total weight of over 600 lbs.) demonstrate the strength of the monorail connection

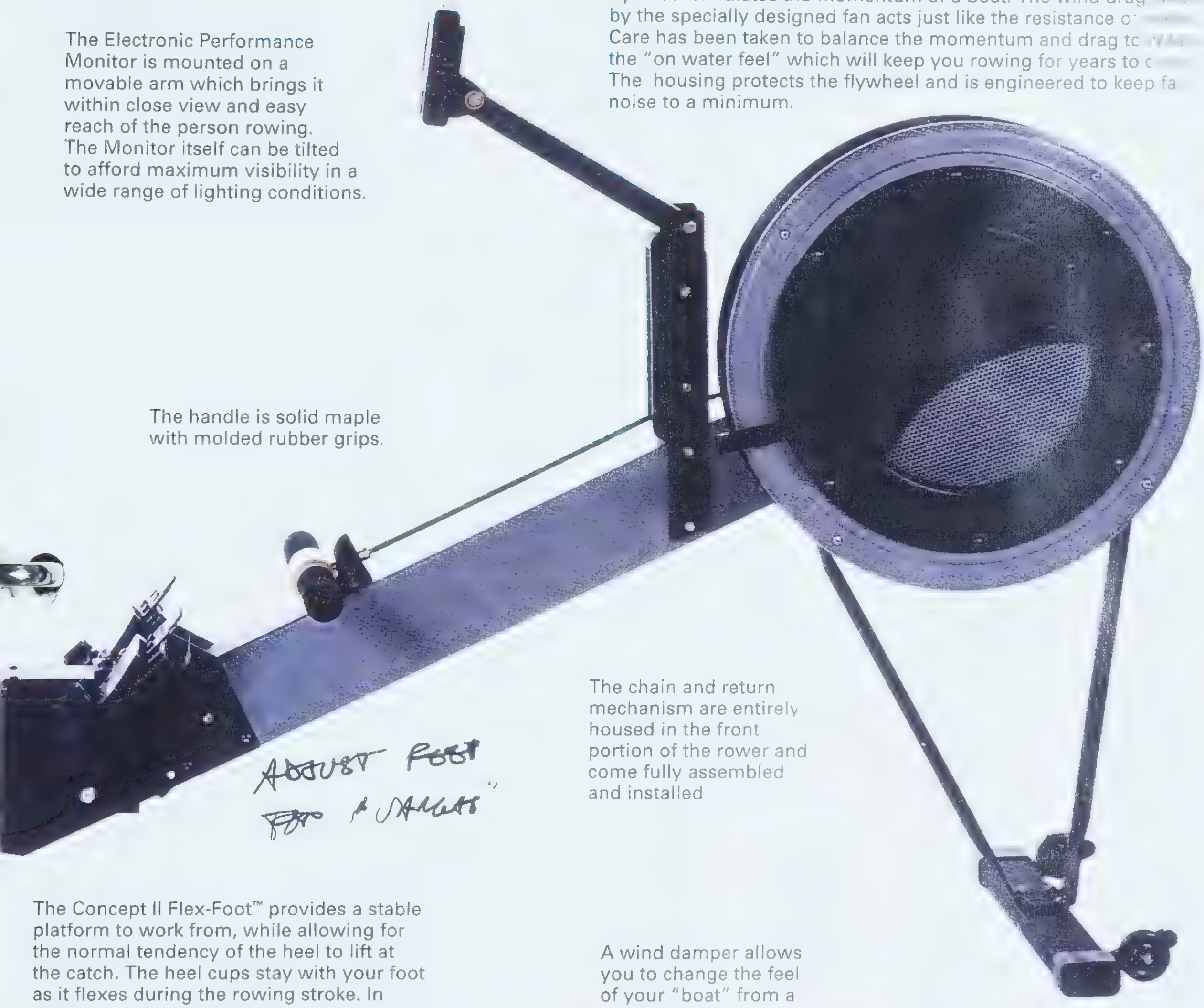
The monorail is joined to the front half of the Indoor Rower with a unique self-locking system and can be detached easily for storage. The rower then fits easily within 28" x 35" of floor space. The monorail piece weighs about 17 pounds. The front end weighs 44 pounds and has built-in casters for easy moving

The Concept II Indoor Rower

Built to last a lifetime.

The flywheel and fan are the heart of the Indoor Rower. The weig[illegible] flywheel simulates the momentum of a boat. The wind drag [illegible] by the specially designed fan acts just like the resistance o[illegible] Care has been taken to balance the momentum and drag to [illegible] the "on water feel" which will keep you rowing for years to c[illegible] The housing protects the flywheel and is engineered to keep fa[illegible] noise to a minimum.

The Electronic Performance Monitor is mounted on a movable arm which brings it within close view and easy reach of the person rowing. The Monitor itself can be tilted to afford maximum visibility in a wide range of lighting conditions.



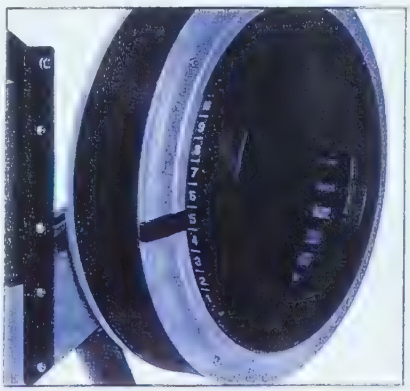
The handle is solid maple with molded rubber grips.

The chain and return mechanism are entirely housed in the front portion of the rower and come fully assembled and installed

ADJUST FOOT
FOR A [illegible]

The Concept II Flex-Foot™ provides a stable platform to work from, while allowing for the normal tendency of the heel to lift at the catch. The heel cups stay with your foot as it flexes during the rowing stroke. In addition, the new design is easily adjustable to fit a wide range of foot sizes.

A wind damper allows you to change the feel of your "boat" from a fast racing shell to a heavy, slow rowboat



Built-in caster wheels make it easy for one person to move the Indoor Rower

The Concept II Indoor Rower ships in one box and requires minimal assembly

Length: 7'11", Width: 24" at front leg
Height: 35", Weight: 61 lbs
Disassembled Dimensions:
35" x 28" x 53"H

Q. Will rowing be too strenuous for me?

A. One of the great features of the Concept II Indoor Rower is that the intensity of the workout is entirely in your control. You control the intensity by how fast you try to pull the handle toward your body. This in turn spins the flywheel, and the faster the flywheel spins, the more resistance you will feel. The Concept II can be rowed at any power level from 0 watts to the limits of human performance.

Q. I hear rowing is a good upper body workout. What about the legs?

A. Rowing on the Concept II Indoor Rower, like rowing in a racing shell, utilizes the full power of the legs as well as the rest of the body. In fact, the majority of the power you generate while rowing comes from your legs. The myth that rowing is an upper body exercise comes from the fact that the word "rowing" is also associated with weight-lifting, piston-style rowing machines, and fixed-seat rowboats.

Q. Is rowing bad for my back?

A. Because rowing uses your back, it will strengthen your back – and it is one of few aerobic exercises that will do this for you. Strengthening your back will help prevent back injuries. As with any physical activity, if you increase the volume and intensity too rapidly, fail to warm up properly, or use poor technique, you will increase the risk of injury.

Q. I have never rowed before. Where can I get information on how to row and what types of workouts to do?

A. Don't worry. We include a package of materials with every rower which includes a description of proper rowing technique, sample workouts, and suggestions for how to get started. In addition, our twice yearly newsletter includes training information, maintenance tips, the indoor race calendar, our Annual World Ranking, and news from Concept II rowers throughout the world. You can also take advantage of our Video Coach program by sending us a VHS recording of yourself rowing. For a small charge, Concept II Coach Larry Gluckman, a former Olympic rower and coach, will add his comments and suggestions to the tape and return it to you

Q. What is the warranty on the Concept II Indoor Rower?

A. The Indoor Rower comes with a 5-year warranty on the metal frame parts and a 2 year warranty on all other parts. We will be happy to send you a full written copy of the warranty if you would like one before you purchase. A copy is included with every machine we ship.

Q. How much maintenance is required?

A. Many health club owners tell us that the Concept II Indoor Rower is one of the most durable and easily maintained machines they own. Under home use conditions, minimal maintenance is required. Under heavy institutional use, certain parts will need periodic replacement.

Q. What if I need technical assistance or spare parts for my Concept II Indoor Rower?

A. Call us toll-free if you have any problems with your Indoor Rower. We have a technician on call for you from 8 AM to 4 PM EST Monday through Friday. You may also fax us a message at 1-802-888-4791 and we will call you back. We offer a complete spare parts service, direct from our factory. All parts are sent with instructions on proper installation. The Indoor Rower's mechanism is entirely housed in the front section and is easily accessible

Q. What if I have questions after I get my Concept II Indoor Rower?

A. Call us toll-free at 1-800-245-5676, Monday through Friday, between 7:30 AM and 5:00 PM EST. Our phone team has first-hand knowledge of the Indoor Rower and will be happy to answer your questions. You are also welcome to fax or write us with your questions

Q. Where can I buy the Co Indoor Rower?

A. We sell directly from our mont. You can order b fax. Please refer to th form for details

Q. What payment methods ar by Concept II?

A. We accept Visa, Masterca and check payments as we fer for foreign customers. C be charged a couple of business d to shipping. We do not offer bill on orders for indoor rowers

Q. How is the Concept II Ind shipped?

A. The Indoor Rower is shipped by one box. See Order Form for sh rates. We cannot ship it by mail with APO or FPO addresses shoul us a domestic UPS-deliverable addres shipping. Overseas orders call for in mation.

Q. How long will it take for my to arrive?

A. This depends on where you live and with the time of year. Usually, we are a to ship within a few days of the receipt your order, but not always. Please call toll-free at 1-800-245-5676 for current ping information

Q. Is it difficult to assemble?

A. The Indoor Rower requires very littl assembly – just the installation of the fron leg and the frame lock, using a total of screws. We include the necessary tool an clear instructions with lots of picture Allow a half hour for the job

Q. How does your 30-day trial offer work

A. If, within 30 days of shipment of yo Indoor Rower, you are not satisfied with you may return it to us. All shipping cost are your responsibility. We will refund th cost of the machine.

ON THE COVER:

1. Will Schaaf, 10, 2nd place Jr., Northern New England Rowing Championships 1992 **2.** John Sargent, 46, Graphic Designer **3.** Beth Salvas, 30, CII Phone Team member, with son Schuyler, 4 **4.** John Tewhill, 38, 1st CII employee to break 8:00 for 2500 meters **5.** Theresa Snow, 15, High School student **6.** Peter Everington, 27, member British Men's eight Eight, silver medalists, 1992 World ater) Championships. **7.** Ann-Marie Stapleton, 27, World Record Holder, Women's 19-29 Lightweights, with a time of 8:55.2 for 2500 meters, and gold medalist at 1993 World (on-water) Rowing championships. **8.** Walter Sargent, 84, Retired Banker **9.** Gary Hazard, 31, Owner, Vermont Furniture Works **10.** Averill Laundon, 55, former 2500 meter record holder for Men's 50-59 Heavyweight, time of 8:08.3 **11.** Nicole Schaaf, 12, 7th Grader and Will's big sister **12.** Dave Gomez, 31, CII employee, High School Soccer Coach, former Vermont High School Decathlon Champion

1 2 3
4 5 6
7 8 9
10 11 12

printed on recycled paper

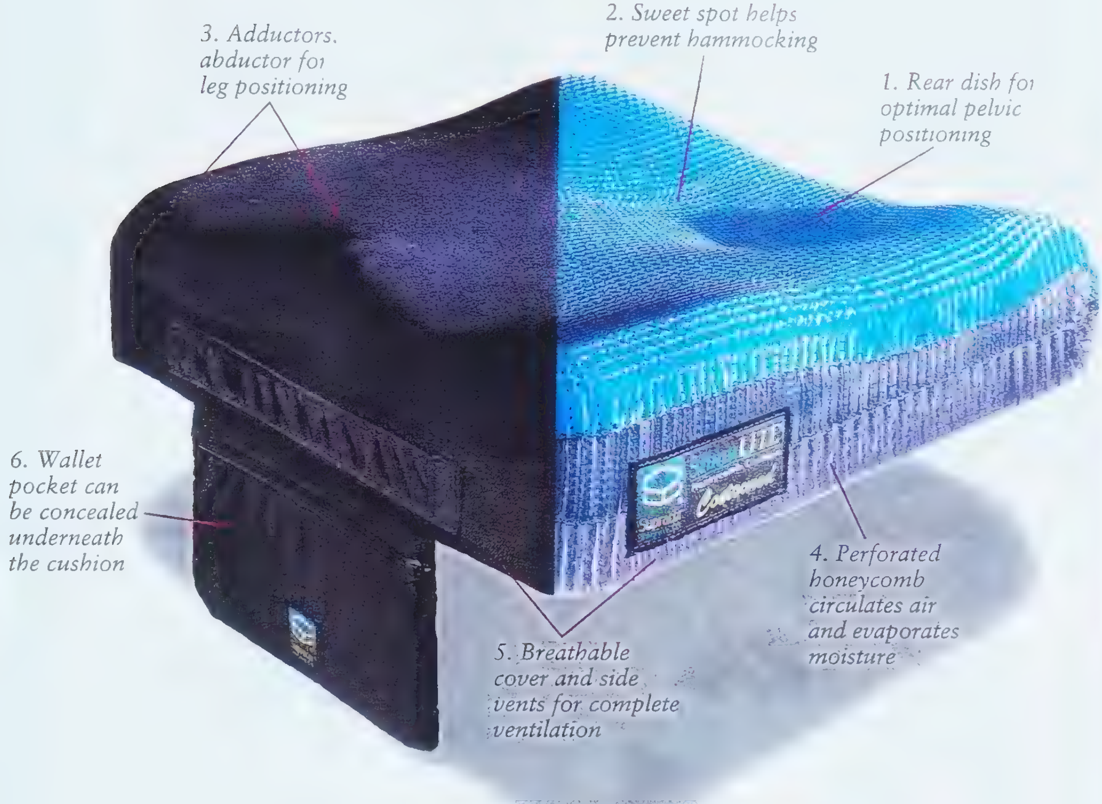
$200.00

Concept II
Indoor Rowe

RR1, BOX 1100,
MORRISVILLE, VT 05661-9727
Toll Free 800-245-5676 (USA & Cana
Monday–Friday 7:30 AM to 5:00 PM ES
Telephone: 802-888-7971
802-888-6333 (Int'l. only)
Fax: 802-888-4791
e-mail: rowing@concept2.com
Web site: http://www.concept2.com

StimuLITE®

Contoured Cushion



Total Pressure Management

The new Stimulite Honeycomb Contoured Cushion addresses the need for positioning while providing superior pressure management. A multilayered honeycomb is shaped into a subtle contour and specially engineered with soft and stiff areas. A *rear dish (1)* provides optimal pelvic positioning for improved posture and stability. The rear dish features a *"sweet spot" (2)*—a softer honeycomb that contains the ischials and coccyx, and helps prevent hammocking. The sweet spot gradually transitions to a stiffer honeycomb, distributing weight away from the ischials and toward the trochanters and thigh area. *Adductors and an abductor (3)* comfortably contain the legs.

Relying on the dynamics of honeycomb and a well-engineered design, Stimulite cushions combat decubitus with their unique approach to Total Pressure Management. Pressure, shearing, and maceration—softening of the skin due to moisture—are the primary causes of decubitus. Stimulite cushions relieve pressure, reduce shearing, and resolve the problem of maceration. All Stimulite cushions feature *perforated honeycomb (4)* which allows air to circulate and moisture to evaporate.

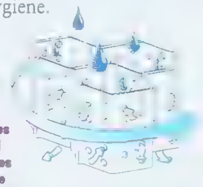
A *breathable cover fabric and side vents (5)* complete the Stimulite ventilation system and keep the user cool and dry. By controlling temperature and moisture, Stimulite cushions combat skin maceration. They are the only cushions that address all causes of decubitus to provide Total Pressure Management.

The Stimulite Contoured Cushion is ideal for paras, quads, and other individuals who require positioning and a high level of pressure management. Weighing just over 3 pounds, the cushion is easy to handle and requires no maintenance. The cover features a *wallet pocket (6)* which can be concealed underneath the cushion. Both cushion and cover are machine washable and dryer safe.

Total Pressure Management

Maceration Resistance

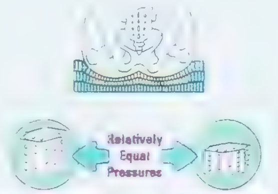
Skin maceration is softening of the skin due to continual exposure to bodily fluids or moisture. Severely softened or macerated skin is less tolerant of pressure and can lead to breakdown. Stimulite honeycomb is perforated, allowing air to circulate through the cushion and moisture to evaporate. A breathable cover wicks away moisture and helps keep the skin dry. Both the Stimulite cushion and its cover are machine washable and dryer safe, making it easy to maintain good skin hygiene.



Complete Ventilation System

Pressure Relief

Honeycomb structure provides uniform load distribution. Stimulite cushions relieve pressure by distributing it away from hot spots. As a result, bony protuberances "feel" the same pressure as the surrounding anatomy. The Stimulite Contoured Cushion distributes weight away from the ischials and towards the trochanters and soft tissues under the thigh. A softer honeycomb—the sweet spot—contains the ischials and coccyx and helps prevent hammocking.



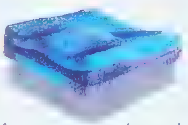
Uniform Load Distribution

Shear Force Reduction

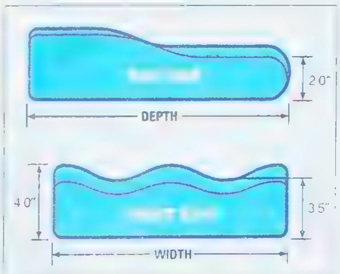
The horizontal stiffness of a cushi[on] material determines both its shear resistance and its stability. Too much stiffness increases shear forces, while too little decreases stability. The three layered Stimulite cushion minimizes shearing without sacrificing stability. The compliant top layer has a low horizontal stiffness for reduced shear forces against the skin. The two bottom layers have a higher horizontal stiffness for optimal stability. The cushion's stretchable cover works in conjunction with the honeycomb to diffuse lateral forces against the skin.

Diffuses Lateral Forces

Stimulite Contoured Cushion



The Stimulite Contoured Cushion is recommended for paras, quads, and other individuals requiring a high level of pressure management in addition to upper body positioning. A rear dish features a sweet spot, softer honeycomb material that contains the ischials and coccyx and helps to prevent hammocking. The sweet spot gradually transitions to a stiffer honeycomb for added support. Adductors and an abductor comfortably contain the legs, without making transferring difficult. Perforated honeycomb allows air to circulate through the cushion and moisture to evaporate. This unique ventilation system reduces skin maceration and facilitates Total Pressure Management.



- *Lightweight — just over 3 lbs*
- *Exceptionally stable*
- *Unique ventilation system*
- *Machine washable and dryer safe*
- *Provides Total Pressure Management*
- *Available in sling bottom for highly slung vinyl seats*

The Stimulite Contoured Cushion is available in width and depth sizes ranging from 14 to 20 inches. A sling bottom version is also available for the highly slung vinyl seat wheelchairs. To order call 1(800) SUPRACOR.

CO MEDICAL EQUIPMENT
303 107 AVE EDMONTON ALTA
S 1K4 FAX:484 8238
800 232 9450 (403) 483 6232

Supracor.

AliMed® Inc.

297 High Street
Dedham, MA 02026

T-Foam™

• The Ideal Cushioning for Special Seating.
• Stability - Pressure Distribution - Comfort.

T-Foam, an open-cell, polyurethane foam, was developed at NASA's Ames Research Center to counteract discomfort from sitting for long periods in space vehicles and to provide shock absorption during take-offs and landings. Self-molding under body heat and weight, T-Foam eliminates pressure build up which may lead to decubitus ulcers or pressure sores. T-Foam comes in four grades, extra soft, (XS), soft, (S), medium, (M), and hard, (H). Firmness and thickness should be matched to the user preference and to climate conditions. In hot, humid climates, the firmer material does best; in dry, cold environments, the softer materials are recommended. T-Foam is used in bed pads, X-ray table pads, flotation pads, wheelchair cushions, and in combination with other AliMed foams, and T-Gels™ to form Combo Cushions.

T-Foam has a remarkable ability to distribute pressure. Squeeze T-Foam and it conforms slowly and easily; pound it and it will not dent. Instead, T-Foam becomes firmer when subject to sudden impact; it absorbs up to 90% of impact shocks and vibration. T-Foam eliminates pressure build up from lying or sitting too long without movement or shifting of positions. Under body pressure and heat, T-Foam contours itself to the body without constantly exerting pressure, enabling blood flow, tissue nourishment and oxygenization to proceed. Lightweight, easy to handle and carry, T-Foam is fire retardant beyond the most stringent Federal Administration guidelines.

SPECS:

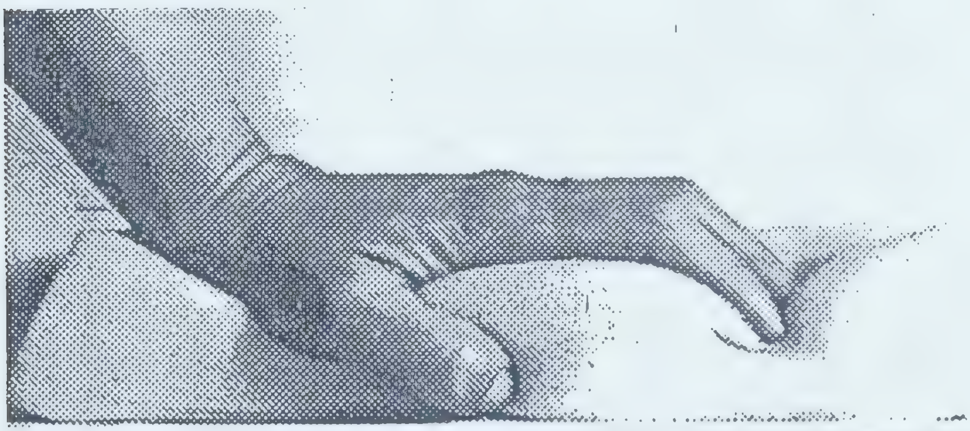
Colors:	Yellow, Pink, Blue, Green
Firmnesses:	X soft, Soft, Medium, Hard
Thicknesses:	Sheets: 1/2" to 3"
	Blocks: 1" to 3"
Surface:	Smooth, cool, dry to the touch
Fire Retardance:	CAL 117, FAR 25.853b

Continued on back.

POSITIONING FOAMS: COMPARATIVE FEATURES

Product	Structural Support	Cell Type	Cushioning	Surface Texture	Conforming*
Constructa Foam, Med	good	closed	limited	grainy	no
Firm	good	closed	poor	grainy	no
X-Firm	excel	closed	poor	board like	no
Super Constructa Foam	fair	closed	good	pleasing	no
SupraFoam	fair	closed	good	rubbery	slight
Positioner Foam	fair	open	good	fine	moderate
T-Foam	poor	open	excellent	silky	excellent

*Conforms and molds to the body.



To order, or for further information,
call AliMed free 800-225-2610, In MA 617-329-2900
24-hr. Fax 617-329-8392

APPLICATIONS	ConstFm	CFf	CFxf	SuperCF	SupraF	Pos.Foam	T-F
abductors: knee, hip, arm	✔	✔	✔	✔			
adductors: knee, hip, arm	✔	✔	✔	✔			
back rests	✔	✔	✔	✔			
trunk supports	✔	✔	✔	✔			
head guides	✔	✔	✔	✔			
head supports	✔	✔	✔	✔			
lapboards	✔	✔	✔	✔			
tray tables	✔	✔	✔	✔			
utensil covers	✔	✔	✔	✔			
arm rests	✔	✔	✔	✔			
foot stabilizers pedals, blocks, boards	✔	✔	✔	✔			
knee supports	✔	✔	✔	✔			
knee bolsters	✔	✔	✔	✔			
wedge seats	✔	✔	✔	✔			✔
corner seats	✔	✔	✔	✔			
inside shoes for support after strokes				✔			
Side lyers	✔	✔	✔	✔			
prone boards	✔	✔	✔	✔			
scooter boards	✔	✔	✔	✔			
stroller inserts	✔	✔	✔	✔			
high chair inserts	✔	✔	✔	✔			
travelling infant seats	✔	✔	✔	✔			
solid seat inserts	✔	✔	✔	✔			
wheelchair basketball solid seat inserts			✔	✔			
elbow conformer splints	✔	✔	✔	✔			
splinting material	✔	✔	✔	✔			✔
splint liners							✔
after-amputation elevation rests	✔	✔	✔	✔			
axilla splints for skin grafts	✔	✔	✔	✔			
Feldenkrais Therapy	✔						
WC cushion	✔	✔	✔	✔	✔	✔	✔
X-ray table pads					✔		✔
flotation pads							✔
cast liners							✔
bed pads							✔
Cushions						✔	✔
exercise mats					✔		
cushioning interface					✔		
artificial limb simulation					✔		

Ordering Information:

T-Foam Blocks, all 16"x 18"	1"(6)		2"(18)		3"(12)	
Firmness	No.	Price	No.	Price	No.	Price
Soft, Pink, T38	#160S	$22.00	#161S	$33.00	#162S	$43.00
Med., Blue,T41	#160M	22.00	#161M	33.00	#162M	43.00
Hard, Green,T47	#160H	24.00	#161H	42.00	#161H	55.00

( ) Indicates case quantities. Save 20% in case lots.

T-Foam Sheets, all 35"x 78"	1/2" (6)		1" (6)		2" (3)		3" (2)	
Firmness	No.	Price	No.	Price	No.	Price	No.	Price
X-S, Yellow,T36	NA	NA	NA	NA	#203	$245.00	NA	NA
S, Pink,T38	268	$75.00	269	$125.00	270	245.00	271	$360.00
M, Blue,T41	274	75.00	275	125.00	276	245.00	277	360.00

( ) Indicates case quantities. Save in case lots. 2" and 3" sheets shipped freight only.

To order, or for further information,
call AliMed free 800-225-2610, In MA 617-329-2900
24-hr. Fax 617-329-8392

APPENDIX C: CMBES Conference

Copy of the abstract and the slides used in the presentation of this project to The Canadian Medical and Biological Engineering Society Symposium. 28-30 June 1998. Edmonton, Alberta.

The Canadian Medical and Biological Engineering Society

La Société Canadienne de Génie Biomédical

Co-sponsor: The Alberta Clinical Engineering Society

Proceedings

Compte Rendu

28 - 30 June/juin 1998

Edmonton, Alberta

ROWING AFTER SPINAL INJURY - New Possibilities Using FES

Garry Wheeler, Rahman Davoodi*, Mandana Asadi*, Brian Andrews*, Yagesh Bhambhani****, Robert Lederer**, Robert Burnham***, Robert Steadward, Louise Miller

Rick Hansen Center, University of Alberta, Edmonton, Canada.
*Department of Biomedical Engineering, University of Alberta, Edmonton, Canada.
**Department of Design, University of Alberta, Edmonton Canada.
***Division of Physical Medicine and Rehabilitation, University of Alberta, Edmonton, Canada.
****Faculty of Rehabilitation Medicine, University of Alberta, Edmonton, Canada.

Cardiovascular disease and stroke are now the leading cause of death and loss of independence in the elderly spinal cord injured person. Immobility and lack of opportunity to exercise at a sufficient level due to the mass of muscle paralyzed is responsible for the early onset of these conditions relative to the able bodied population. In general, SCI people overuse their arms in wheeling and transfer activity and in consequence painful shoulder syndromes are prevalent. With the support of the local SCI advocacy group SCITCS and the Alberta Paraplegic Foundation, a convenient and affordable mode of exercise was sought that would exacerbate rotator cuff injury or shoulder pain, that would conveniently allow a sufficient level of cardiovascular stress to induce a training effect and would be suitable for home use.

Preliminary physiological results involving paraplegic and quadriplegic (incomplete lesions) volunteers using an open-loop FES prototype indicate that higher levels of cardiovascular stress can be obtained that with FES bicycling. The results of computer modeling of the closed dynamical chain using WorkingModel 3D are presented suggesting that improved control may be achieved. Since this is a cybernetic system the paralyzed lower limbs must act in synchrony with the upper body in order to achieve higher stroke rates.

We have developed an affordable FES rowing machine based on standard device (ConceptII). The standard seat is exchanged for a custom designed unit for the spinal injured person. The system may be easily returned to its standard form to enable other members of the household to use it. FES is applied using surface electrodes and a rule based closed loop control system has been implemented using a 68332 microcomputer. It is also possible to connect the system via a PC to the internet to enable competitive racing involving many individuals. To date SCI users have reacted positively to the device, many liking the fact that it is allows them to do the same exercise as friends and family.

The prototype will be displayed together with on-line demonstrations of computer simulations.

Rowing after spinal cord injury: new possibilities for FES

Garry D. Wheeler Ph.D.., C.Psych

24th Annual Conference of the Canadian Medical and Biological Engineering Society

Introduction

- ✓Health and fitness of spinal cord injured
- ✓The importance of physical activity
- ✓FES assisted standing - Dr. Andrews
- ✓FES-assisted exercise technologies - Dr. Wheeler and assoc..
- ✓ROWSTIM II - FES assisted rowing technology for SCI

A Rationale

- ✓Early demise of SCI
- ✓CV disease - #1 cause of death in SCI
- ✓Lack of physical activity is #1 risk factor
- ✓Limited opportunities for SCI
- ✓Available technologies inadequate
- ✓Chronic overuse syndromes in the shoulder

Activity solutions needed that -

- ✓ Recruits sufficient muscle mass for central cardiovascular training effect
- ✓ Reduces overuse injury in shoulder
- ✓ Is adaptable to Paraplegia, Quadriplegia
- ✓ Is adaptable for SCI and AB
- ✓ Is affordable
- ✓ Is ecologically valid - Perceived as "realistic"
- ✓ Is suitable for home use

Health of spinal cord injured

- ✓Cardiovascular disease - major threat to longevity and #1 factor in demise of SCI (Bauman et al., 1992)
- ✓Lifespan decreased by a decade compared to AB population (Menter and Hudson, 1995)
- ✓Decreased health and opportunities result in decreased health related QOL

Bottom Line

Cardiovascular disease is the number one cause of death in the SCI population

Bottom Line

Critical to provide exercise opportunities for persons with SCI

Able bodied picture

- ✓66% of Canadians insufficient activity
- ✓40% of Canadian children insufficient activity
- ✓80,000 deaths associated with circulatory disease
- ✓Cost of $17 billion in direct/indirect costs
- ✓50% preventable?

Challenges to fitness in SCI

- ✓ **Autonomic dysfunction**
- ✓ **Circulatory hypokinesis**
- ✓ **Decreased functional muscle mass**
- ✓ **Structural overuse syndromes**

Exercise opportunities for SCI

- ✓ Wheelchair ergometers
- ✓ Arm crank ergometers
- ✓ Upper extremity resistance training
- ✓ ***FES assisted exercise technologies***

Functional Electrical Stimulation-Assisted Exercise

FES technologies to date

- ✓Resistance training - HYDRASTIM
- ✓Cycle ergometry - ERGYS I, II
- ✓Wheelchair FES interfaces
- ✓Hybrid systems - combined arm ergometry and ERGYS
- ✓ROWSTIM I - pilot

Benefits of FES

✓INCREASED

- ✓ cardiorespiratory fitness
- ✓ peripheral blood flow
- ✓ muscle tone and strength
- ✓ type I muscle fibers
- ✓ bone mass
- ✓ well being

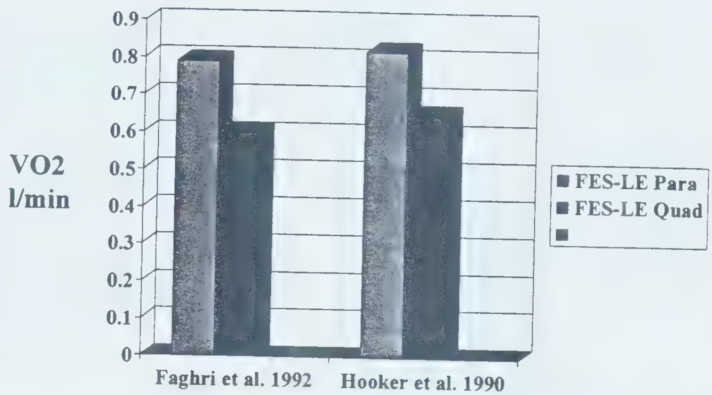
✓DECREASED

- ✓ peripheral resistance
- ✓ risk for CV disease
- ✓ venous pooling
- ✓ risk for DVT
- ✓ risk for decubitus ulcers
- ✓ spasticity

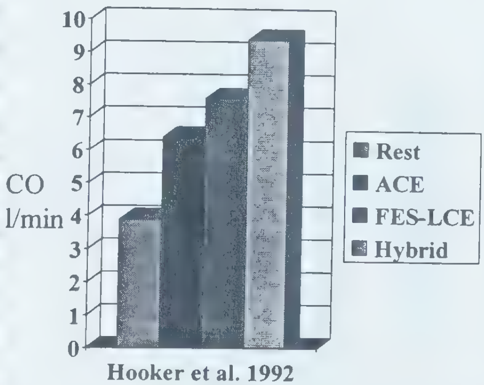
Problems with FES training systems

- ✓ Recruitment of limited muscle mass
- ✓ Minimal cardiovascular training effect
- ✓ Expensive
- ✓ Non-portable
- ✓ Exclusive to SCI
- ✓ Labour intensive
- ✓ Safety issues
- ✓ Perceived as unrealistic by patients

Responses - Quads v Paras



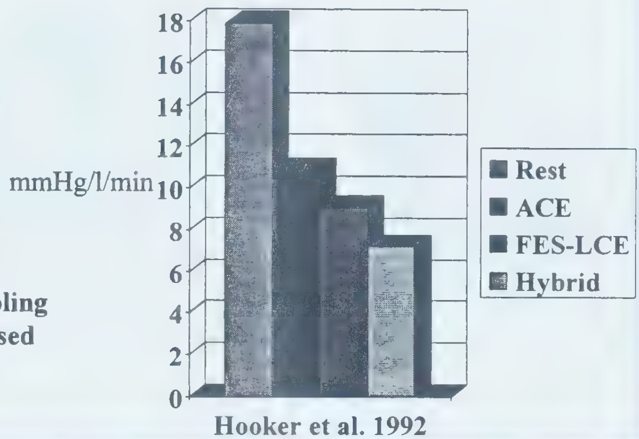
Increased Cardiac Output



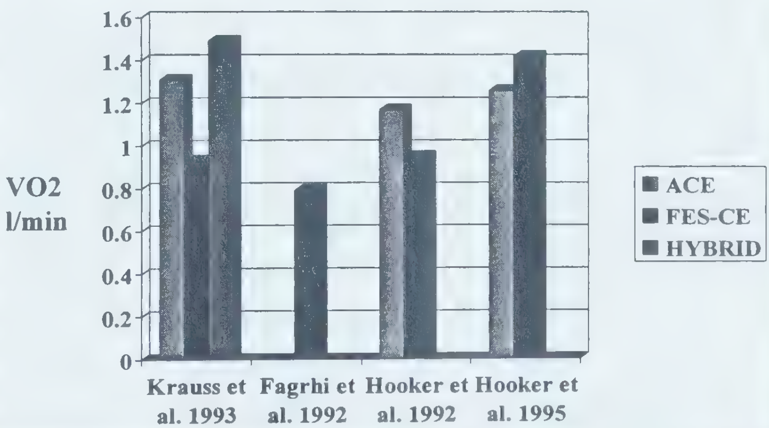
- ✓ Cardiac output by non-invasive impedence cardiography
- ✓ Stroke volume x HR
- ✓ Increases from rest to ACE
- ✓ ACE to FES-LCE
- ✓ FES-LCE to Hybrid

Decreased peripheral resistance

- ✓ Total peripheral resistance decreased across all conditions
- ✓ Indicates decreased venous pooling and increased blood flow

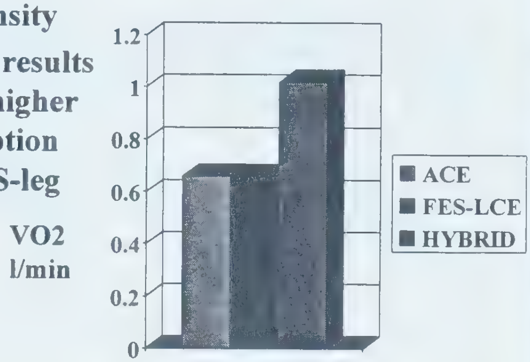


Hybrid systems @ max exercise intensity



Hybrid systems @ submaximal exercise intensity

- ✓ @ sub max intensity
- ✓ Hybrid exercise results in significantly higher oxygen consumption than arm or FES-leg exercise alone



Hooker et al. 1992

Difficulties in comparing research

- ✓ Small numbers
- ✓ Heterogeneity of samples (lesion levels)
- ✓ Length of programs
- ✓ Titration of work volume
- ✓ Assisted or unassisted programs
- ✓ Lack of control groups
- ✓ Interval versus continuous programs
- ✓ Absolute VO2 max v relative VO2 max
- ✓ Degree of work achieved during timed intervals

ROWSTIM II FES rowing

Review of research leading to design

- ✓ Shoulder pain in wheelchair athletes. The role of muscle imbalance *(Burnham et al., 1993)*
- ✓ Electrical stimulation-assisted rowing exercise in spinal cord injured people: A pilot study *(Laskin, Wheeler et al., 1993).*
- ✓ Efficacy of rowing, backward wheeling and isolated shoulder scapular retractor exercise as remedial strength activities for wheelchair users *(Olenik, Wheeler et al., 1995)*
- ✓ Home exercise for paraplegics using FES *(Miller, Andrews, Wheeler et al., 1997)*

Pilot study - Rowstim I

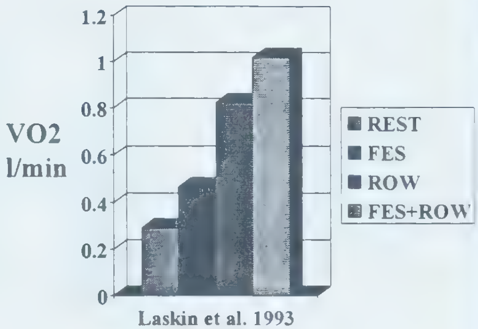
- ✓ Adapted Concept II model A rower
- ✓ Sliding bucket seat and leg guides
- ✓ Stabilizing system and elastic return
- ✓ Open loop manual electrical stimulation control - QUADSTIM
- ✓ Adapted cycle shorts with sewn in pockets for electrodes

Protocol

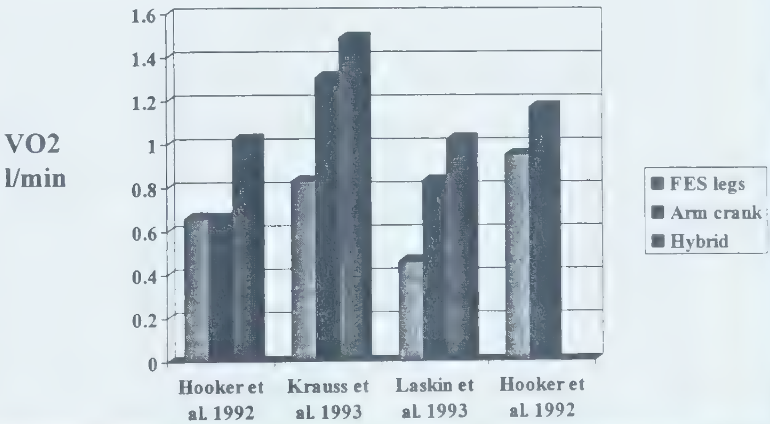
- ✓ Arm ergometry VO2 max.
- ✓ *Criteria for rowing*
  - incremental stimulation intensity for full flexion and extension
  - stroke rate @ 15 strokes per minute
- ✓ *3 rowing conditions*
  - STIM - legs only
  - ROW - arms only
  - R&S - upper and lower extremity activity

Results

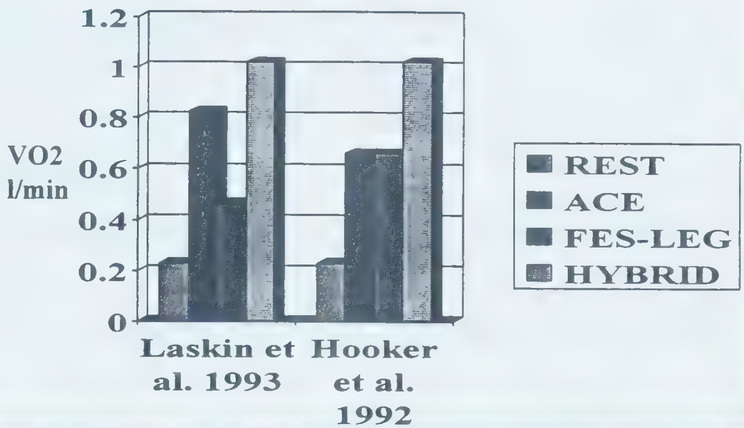
- ✓ A linear increase in oxygen cost of
  - rest
  - leg stimulation (FES)
  - arm rowing activity (ROW)
  - combined FES + ROW



Efficacy of rowing…..



Rowing and sub-maximal exercise



The ROWSTIM II - specifications

- ✓ Standard Concept II rowing ergometer
- ✓ Closed loop neuromuscular stimulation control
- ✓ Specially designed sliding seating system and restraints
- ✓ Mechanical braking system**
- ✓ Optical encoding system - define technique stage - drive - lean - pull - recovery
- ✓ Integrated stimulator and controller
- ✓ “oar” support system

Development of seating system

- ✓ Purpose: develop a seat that -
- ✓ facilitates ease of transfer
- ✓ support low and high lesion clients
- ✓ is stable
- ✓ provides adequate support to avoid pressure sores
- ✓ can be readily changed to standard seat system

Importance of manual braking system

- ✓ During pull phase - maximal action reaction forces on legs
- ✓ Mechanical braking system operates during pull phase
- ✓ Stablizes legs in extended position

Training client for FES rowing

- ✓ Establishing electrode placement
- ✓ Transfer
- ✓ Leg extension-flexion familiarization
- ✓ Arms only phase
- ✓ Combined arms and legs phase - single cycles
- ✓ Complete rowing
- ✓ Interval rowing
- ✓ Continuous rowing

Safety - Autonomic Dysreflexia

- ✓ *Autonomic dysreflexia during functional electrical stimulation assisted exercise*
- ✓ Laskin et al. (1993) - FES rowing
- ✓ Ashley et al. (1993) - Evidence of autonomic dysreflexia during FES stimulation……….
- ✓ Matthews et al. (1997) - The effects of surface anaesthesia on the autonomic dysreflexia response during FES

Control of Rowing in Paraplegia

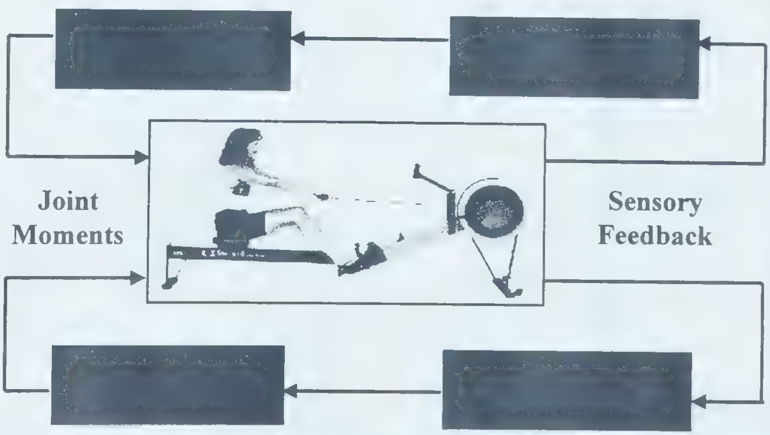
Rowing Exercise needs the coordinated activation of the upper and lower extremity muscles by the CNS.

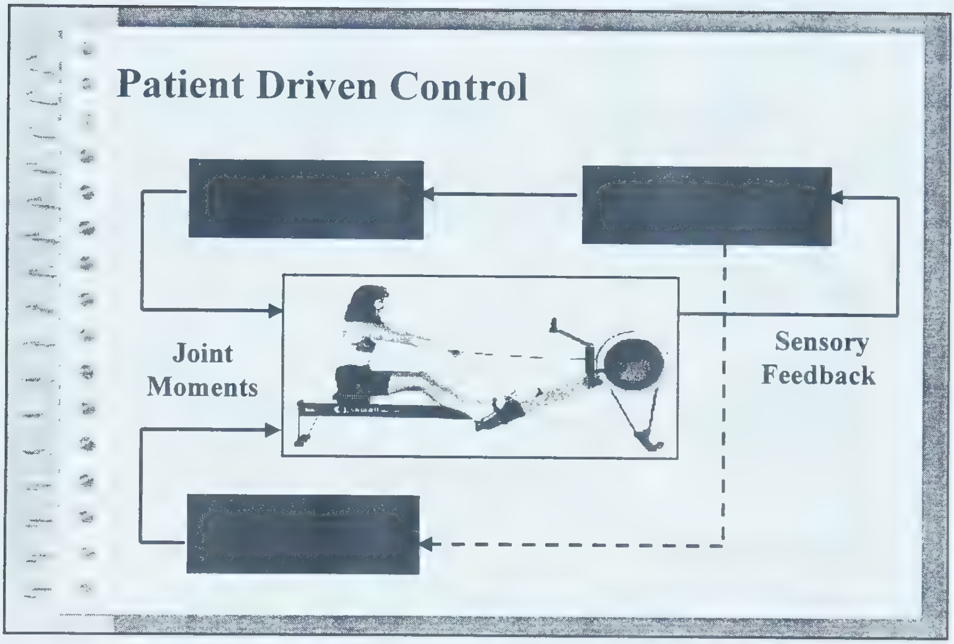
In Paraplegia: Two separate controllers

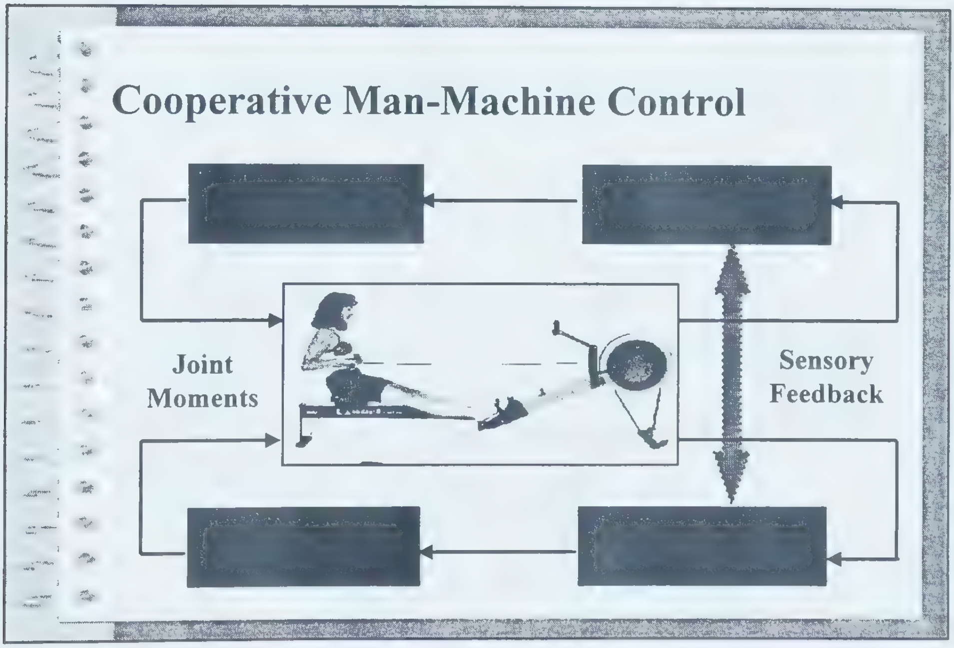
Arms:
Controlled Voluntarily

Legs: Controlled by FES

Man-Machine System

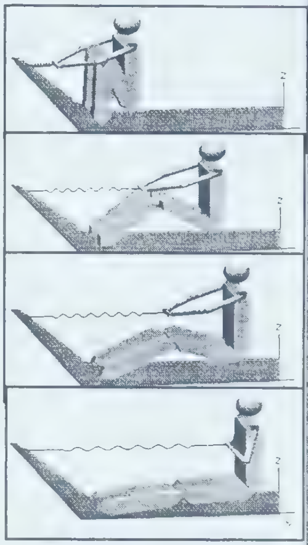



Patient Driven Control
Joint
Moments
Sensory
Feedback


Cooperative Man-Machine Control
Joint
Moments
Sensory
Feedback

Computer Simulation

Includes: nine rigid segments, handle and seat/break assembly. **Developed by:** Working Model 3D.



Applications:

- ♦ Gain insight into motion dynamics.
- ♦ Design/Debug controllers.
- ♦ Compare different control strategies and mechanical configurations.
- ♦ Analyze sensitivity to parameters.
- ♦ Patient safety in initial development.

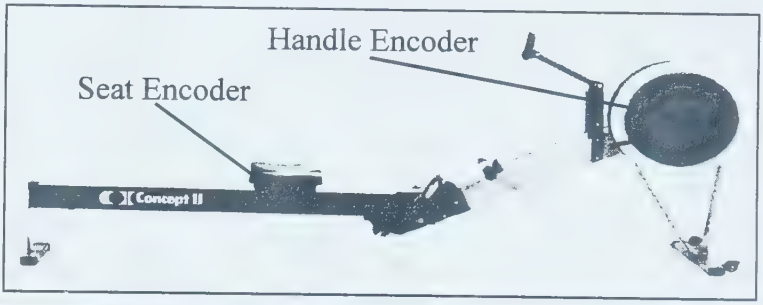
Instrumentation: Electrical Stimulator

- ♦ Based on Motorola MC68332 a versatile and powerful microprocessor.
- ♦ Acquires positional data from sensors in seat and handle.
- ♦ Good computational power for real-time calculations of the sophisticated controllers.
- ♦ Four channels of electrical stimulation to activate the quadriceps and hamstrings of the left and right legs.
- ♦ Communicates with subject via Buttons, switches, LCD etc.

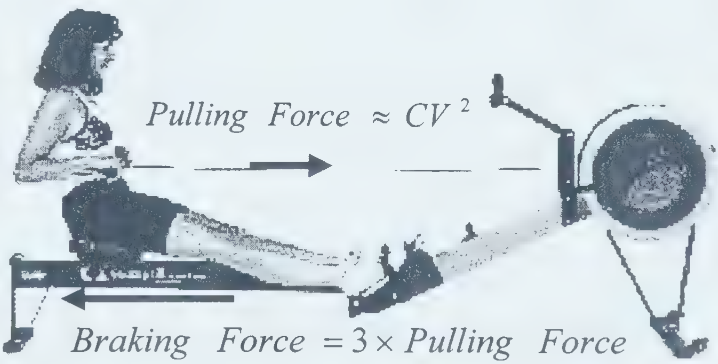
Instrumentation: Feedback Sensors

Two optical encoders measure the position of the seat and handle.

No sensors mounted on the subject.



Instrumentation: Proportional Brake



APPENDIX D: Ethics Approval

Copy of Health Research Ethics Approval

University of Alberta
Edmonton
Canada T6G 2G4

Faculty of Rehabilitation Medicine
Rehabilitation Research Centre
3-48 Corbett Hall
Director (403) 492-7856 Telephone (403) 492-2903
Fax (403) 492-1626

UNIVERSITY OF ALBERTA HEALTH SCIENCES FACULTIES, CAPITAL HEALTH AUTHORITY, AND CARITAS HEALTH GROUP

HEALTH RESEARCH ETHICS APPROVAL

Date: July 1998

Name(s) of Principal Investigator(s): Dr. Garry Wheeler

Organization(s): University of Alberta

Department: Rick Hansen Centre and Faculty of Physical Education and Recreation

Project Title: A Home-based Electrical Stimulation-assisted Rowing Exercise Program for Persons with Spinal Cord Injury.

The Health Research Ethics Board has reviewed the protocol for this project and found it to be acceptable within the limitations of human experimentation. The HREB has also reviewed and approved the patient information material and consent form.

The approval for the study as presented is valid for one year. It may be extended following completion of the yearly report form. Any proposed changes to the study must be submitted to the Health Research Ethics Board for approval.

University of Alberta
Edmonton

Faculty of Rehabilitation Medicine
Rehabilitation Research Centre

UNIVERSITY OF ALBERTA HEALTH SCIENCES FACULTIES,
CAPITAL HEALTH AUTHORITY, AND CARITAS HEALTH GROUP

HEALTH RESEARCH ETHICS APPROVAL

Date: July 1998

Name(s) of Principal Investigator(s): Dr. Garry Wheeler

Organization(s): University of Alberta

Department: Rick Hansen Centre and Faculty of Physical Education and Recreation

Project Title: A Home-based Clinical [illegible] of Stimulation-assisted [illegible] Exercise Program for Persons with Spinal Cord Injury

Slides:

1) Overview of exercise machine
2) Close-up of seat - transfer arm up
3) Close-up of seat - transfer arm down
4) Back of seat
5) End of travel dampners
6) Underview of seat carraige - showing brake system
7) Brake mechanism at handle
8) Handle showing FES activation switches
9) Front view of seat
10) Knee supports
11) Client in full harness - front view
12) Client in full harness - side view
13) Side view - no shoulder straps
14) Feet straps
15) Transfer bar in place
16) View of seat - cushion removed
17) Transfer bar - anchor point
18) Optional seat return strut